Numerical scores of 0, 2, 4, 6, 8, and 10 were assigned to the standards, 0 representing the smallest degree of discoloration, 10 the most.

A panel of four judges scored all bones. The standards referred to above were placed before the judges during each scoring period. Code numbers were given to the bones being scored to conceal the nature of the treatment of the birds. All bones were photographed in color for future reference.

The scores were analyzed statistically by the analysis of variance method of Snedecor *(10)*.

Age and Breeding of the Birds. To study the effect of the age of the birds in Experiment I, New Hampshires 7, 8, 10, 12, 14, 16, and 17 weeks of age were frozen at —10° F. and stored at 0° F. for three to five weeks prior to defrosting, cooking and scoring. A comparison was also made between unfrozen and frozen, defrosted yearling New Hampshire hens.

In Experiment II, both "purebred" and "crossbred" birds were used. The purebred birds used were New Hampshires, White Wyandottes, White Rocks, and White Leghorns. The crossbred birds included three Leghorn crosses (i.e. progeny of White Leghorn males and crossbred "heavy" females). In addition, progeny of New Hampshire Barred Rock and New Hampshire Black Australorp crosses were used. All birds were approximately 12 weeks of age when slaughtered and were held in frozen storage at —10° F. for two weeks or longer prior to defrosting, cooking and scoring.

Processing Prior to Freezing. In Experiment III, different chilling methods were employed. Ice slush was used to chill one lot of New York dressed carcasses and one lot of disjointed carcasses. One lot of New York dressed carcasses was chilled in air at 35° F. and one lot of birds was disjointed and frozen without a chilling period according to the routine procedure described previously. Another lot of birds was frozen as New York dressed carcasses, defrosted, disjointed, and refrozen. All lots in this experiment were frozen at —30° F. and stored at 0° F. for six weeks prior to defrosting, cooking and scoring.

The effect of bleeding was studied in Experiment IV by altering the length of time allowed for bleeding to take place. One lot of birds was killed and defeathered without any bleeding and frozen without evisceration. In another lot of birds bleeding was stopped at the end of 20 seconds by applying a ligature to the neck. These birds were also frozen without evisceration. Three additional lots of birds were bled for the full bleeding period (one minute). One of these lots was frozen as New York dressed carcasses, one as eviscerated whole carcasses, and one as disjointed carcasses. All lots were frozen at —30° F. and stored at 0° F. for seven weeks prior to defrosting, cooking, and scoring.

In Experiment V disjointed carcasses were packed in quart-size Mason fruit jars and covered with various solutions before freezing. One lot of birds was frozen in each of the following solutions: distilled water; 0.425, 0.85, 1.7 and 13 percent NaCl; 0.2 percent ascorbic acid and 0.5 percent KNO_3. All lots were frozen at —30° F. and stored at 0° F. for 30 to 35 days prior to defrosting, cooking and scoring.

In Experiment VI, the bone marrow was removed from the leg and thigh bones of two lots of birds. The bones in one lot were split lengthwise with a band saw to remove the marrow. In the other lot, one-eighth-inch holes were drilled in each end of the bones and the marrow was flushed out with a stream of water. A control lot was prepared according to the routine procedure given previously. All three lots were frozen and stored at —10° F. for 18 days prior to defrosting, cooking and scoring.

Freezing, storing and thawing. Experiment VII was designed to study the effect of storage temperature and length of storage on bone darkening. Birds were frozen at —30° F. and transferred to various storage temperatures so that one lot of birds could be withdrawn from each of the storage temperatures 20° F., 10° F., 0° F., —10° F., and —30° F. after 24 and 96 hours and 1, 4, 16, 24 and 36 weeks of storage. A total of 210 birds were used. In addition, five lots of birds were allowed to freeze and remain in storage for four weeks, one at each of the temperatures 20° F., 10° F., 0°F., —10° F., and —30° F.

Experiment VIII was designed to determine the effect of temperature fluctuation during frozen storage on bone darkening. Two storage temperatures, 20° F. and —10° F., were used. Three lots were transferred from one storage temperature to the other at 7 to 10 day intervals. For controls, a lot of birds was stored at each of these temperatures for the entire storage period of six weeks.

In Experiment IX, four lots of birds were frozen and stored at —30° F . A fifth lot was frozen and stored at —10° F. At the end of the five-week storage period the control lot that had been frozen and stored at —30° F. was thawed overnight at room temperature prior to cooking and scoring. Two lots stored at —30° F. were thawed in hot (140° F.) running water. One of these lots was cooked immediately, but the other was stored 72 hours at 35° F. prior to cooking. One lot stored at —30° F. and one stored at —10° F. were placed in the oven to cook without prior defrosting.

Cooking. Experiment X compared methods of cooking frozen, defrosted birds. All lots of birds had been frozen and stored at —10° F. for seven and one-half weeks. One lot was cooked by roasting for one hour in an electric oven regulated at 300° F. Another lot was cooked by frying in "deep" fat at 300° F. in a covered cast-iron frying pan for 40 minutes. Two hundred grams of fat were used for each bird, giving a depth of about one-half inch, and the pieces were turned at ten-minute intervals. A third lot was simmered in water at 209° F. for 45 minutes. One liter of water was used for each bird.

Experiment XI was designed to determine whether precooking before freezing would prevent the development of dark bones. One lot of birds was cooked for 15 minutes, a second for 30 minutes, a third for 45 minutes, and a fourth was cooked for one hour prior to packaging and freezing. The oven temperature was regulated at 300° F. and the position of the trays in the oven was interchanged at the midpoint of the cooking period. The control lot was not precooked.

All lots were frozen and stored at 0° F. for five weeks. They were then removed from storage and thawed overnight at room temperature. Each lot was cooked for a sufficient length of time so that the total cooking period before and after freezing totalled one hour. A period of five minutes was added to the cooking time of all precooked lots to compensate for being at room temperature when cooking was resumed. The lot that had been precooked for 60 minutes (a full cooking period) was also given the additional five-minute cooking period to simulate the heating of precooked foods before serving. The control lot was cooked for the usual period of one hour.

Results and Discussion

General. Figure 1 shows all the bones from the left halves of the roasted carcasses of two 12-week-old New Hampshire males. All bones of the frozen bird (B) were somewhat darker than those of the unfrozen one (A), but the bones most seriously affected were the leg, thigh and coracoid. The wing bones, breast bone, and "saddle" portion of the back were not greatly discolored.

FIG. 1. The effect of freezing on the discoloration of the bones of fryers.

(A—Unfrozen control; B—frozen. Bones shown are from half carcasses only. Birds were 12-week-old New Hampshires; they were roasted.)

On the basis of these observations it seemed logical to use all bones except those in the wings for routine examination in future studies. These bones were the legs, thighs, coracoids, backs and keel bones of each bird.

Comparisons of the average color scores of bones from birds that were cooked without freezing and from birds that were cooked after freezing and defrosting are presented in Figure 2. The average color scores clearly indicate that only the legs, thighs, and coracoids are darkened to a sufficient extent to be of practical importance. While it is possible to find back and breast bones that vary in color, freezing and thawing do not appear to be contributing factors. Because of these findings it was decided that only the color scores of legs, thighs, and coracoids would be used.

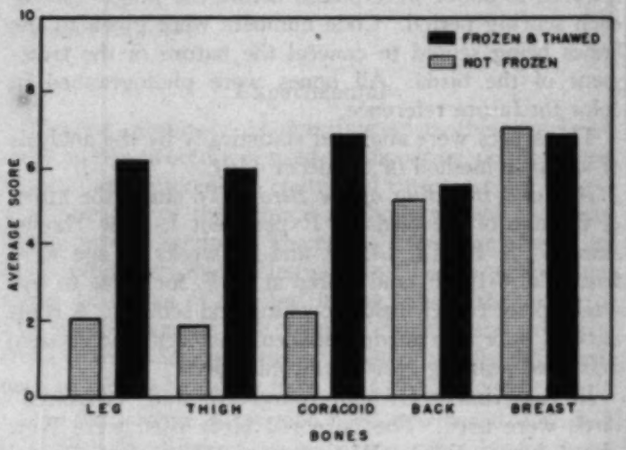

FIG. 2. Effect of freezing on discoloration of the various bones of fryers.

(12-week-old New Hampshires used. Birds roasted. Data includes scores from 4-6 birds. Scoring range, 0-10; 0 equals smallest amount of discoloration.)

The "average total score per bird" is the *sum* of the scores of these six bones from each bird. The score of each bone was obtained by averaging the scores given that bone by the four judges. With a range of 0-10 for each bone the highest score an individual bird could have was 60. Since there were six replicate birds in each lot the average of the *total* scores of six birds gave the "average total score per bird" for each treatment.

Figure 3 shows photomicrographs of smears of bone marrow from the tibiae of 12-weeks-old New Hampshires. The top figure (A) shows the marrow from an unfrozen bird. Note the large number of nucleated red blood cells. They appear as oval-shaped cells with deeply stained nuclei. The other cells are largely "white" blood cells. Figure 3B shows the marrow from a bird that had been frozen and thawed prior to the preparation of the smear. Here it is clear that there is complete absence of cellular material; only nuclei can be seen. Freezing and thawing apparently liberated the hemoglobin of the red blood cells into the bone marrow cavities.

Since freezing and thawing hemolyze the red blood cells of the bone marrow, the question arises as to whether that is the sole cause of dark bones. If so, then hemolysis of the bone marrow erythrocytes by other means should result in darkened bones without freezing.

To effect hemolysis without freezing, a 2 percent solution of saponin was injected into the marrow cavities of the leg and thigh bones of six disjointed birds. One lot of frozen birds and one lot of unfrozen birds

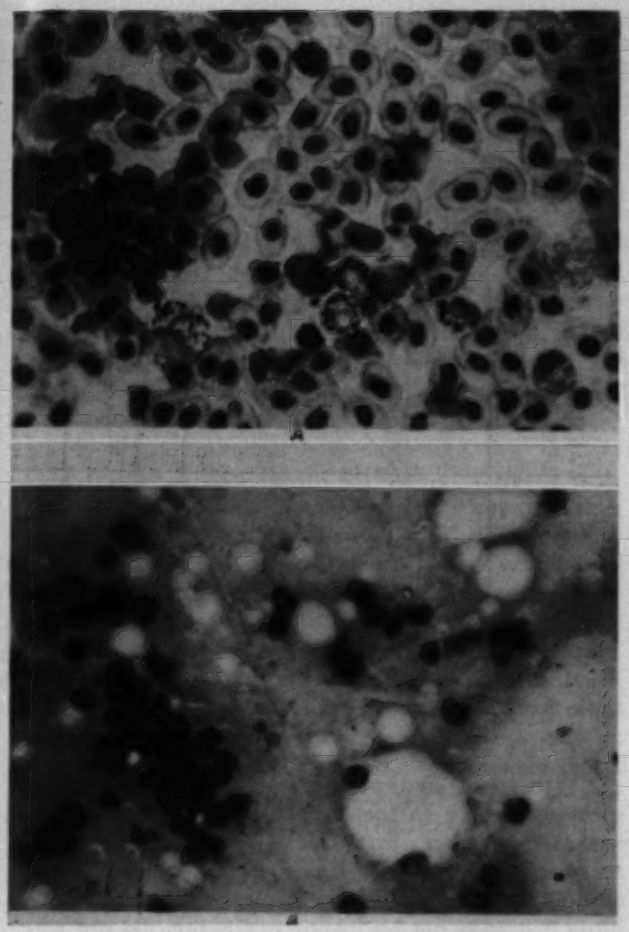

FIG. 3. Photomicrographs of bone marrow from tibia of unfrozen (A) and frozen-thawed (B) fryers.
(12-week-old New Hamphshire male used. Wright's stain; magnification 450 x.)

were prepared at the same time for comparison. The average bone-color scores are shown graphically in Figure 4. Only the leg and thigh bones could be treated, since the caracoids are not easily accessible. Microscopic examination of the marrow from bones treated with saponin revealed that complete hemolysis of all red blood cells had been accomplished.

The average bone-color scores show that the injected bones (lot B) did not darken appreciably; certainly they did not approach the discoloration of the frozen birds (lot C). Statistical analysis showed that lots A and B were not significantly different while lot C was significantly different from both lots A and B at the 1 percent level. Since the bone marrow of both lots B and C had been hemolyzed, but only lot C had been frozen, it appears that hemolysis of the red blood cells in the bone marrow is not the only function of freezing and thawing in producing dark bones.

Age and Breeding of the Birds. The results of Experiment I concerning the effect of the age of the birds on bone darkening are shown in Figure 5. Statistical analysis revealed that average bone color scores for birds 16-17 weeks of age were significantly lower than the others. Younger birds did not differ in their susceptibility to bone darkening when frozen.

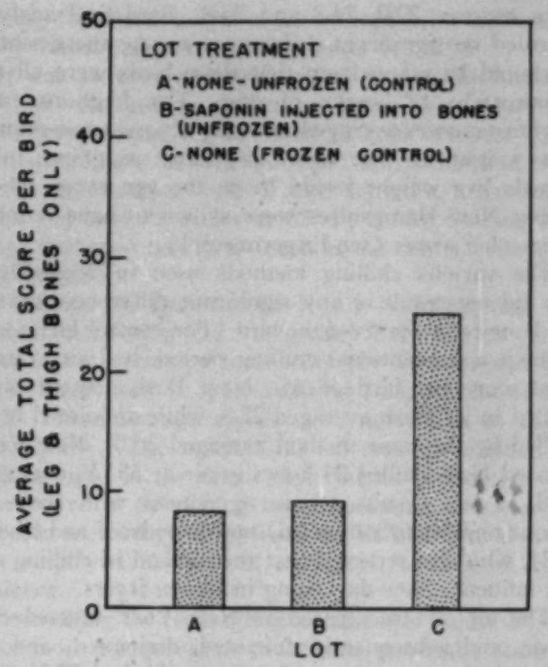

FIG. 4. The effect of hemolyzing bone marrow erythrocytes with saponin on discoloration.
(12-week-old New Hampshire fryers used.)

No scores were taken on the bones of the yearling New Hampshire hens but it was noted that there were no appreciable changes in bone color of these mature birds as a result of freezing and thawing. Similar observations were reported by Koonz and Ramsbottom *(6)* and Woodroof and Shelor *(13)*.

In Experiment II, in which the genetic background of the birds was the variable, the following average total scores per bird were obtained: New Hampshires, 34.3; White Leghorns, 30.7; White Wyandottes, 27.1; White Rocks, 24.6; Barred Rock x New Hampshire crosses, 26.9 and 28.3; Indian River crosses, 28.3; Black Australorp x New Hampshire crosses, 27.3; White Leg-

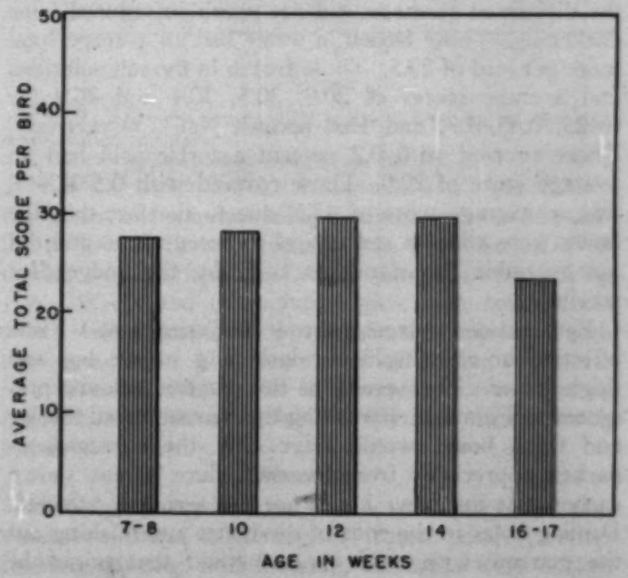

FIG. 5. Effect of age of bird on bone discoloration due to freezing.
(12-week-old New Hampshire fryers used.)

horn crosses, 29.9, 24.8 and 24.8. Statistical analysis revealed no significant differences among these scores. It should be pointed out that these birds were all approximately 12 weeks of age. The Leghorns and Leghorn crosses averaged only slightly over two pounds live weight at that age. Leghorns weighing three pounds live weight would be in the age range where frozen New Hampshires were shown to have reduced bone color scores (see Experiment I).

The various chilling methods used in Experiment III did not result in any significant differences among the bone color scores of the bird. The control lot, frozen without a conventional chilling period, had an average total score per bird of 25. New York dressed birds chilled in ice slush averaged 23.8, while disjointed birds chilled by the same method averaged 26.0. New York dressed birds chilled 24 hours in air at 35° F. averaged 26.8. These results are in agreement with those of Koonz and Ramsbottom *(6)* and Woodroof and Shelor *(13)*, who also reported that the method of chilling did not influence bone darkening in frozen fryers.

The lot of birds frozen as New York dressed carcasses and subsequently defrosted, disjointed, and refrozen had an average total score per bird of 27.3. This score was not significantly different from that of birds frozen only once. Koonz and Ramsbottom *(6)* stated that treating birds in this manner resulted in increased darkening but presented no data.

The average total scores per bird obtained in Experiment IV concerned with extent of bleeding were as follows: bled one minute and disjointed, 36.2; eviscerated, 41.3; New York dressed, 36.4; birds bled 20 seconds averaged 34.4, and those not bled averaged 38.7. The scores did not differ significantly, indicating that neither the extent of bleeding nor the degree of carcass separation materially affect bone darkening in frozen fryers. The findings are at variance with those of Woodroof and Shelor *(13)*, who reported that "poor" bleeding resulted in increased bone darkening.

In Experiment V, the various solutions used to cover the disjointed carcasses did not result in reduced bone darkening. Those frozen in water had an average total score per bird of 29.5. Those frozen in the salt solutions had average scores of 20.9, 30.5, 30.1 and 26.9 for 0.425, 0.85, 1.7, and 13.0 percent NaCl, respectively. Those covered with 0.2 percent ascorbic acid had an average score of 29.0. Those covered with 0.5 KNO_3 had an average score of 43.1, due to the fact that the bones were a bright red typical of cured meats and did not resemble the standards used by the judges for scoring.

Removal of the bone marrow in Experiment VI was effective in reducing bone darkening in the leg and thigh bones. The results of this experiment are presented in Figure 6. Removing the marrow from the leg and thigh bones would leave only the coracoids to darken appreciably from freezing, since it was shown earlier that the other bones are not seriously affected. Drilling holes in the ends of the bones and flushing out the marrow with water is a method that might be adopted for rapid and inexpensive use if industry finds the "dark bone" problem is sufficiently serious.

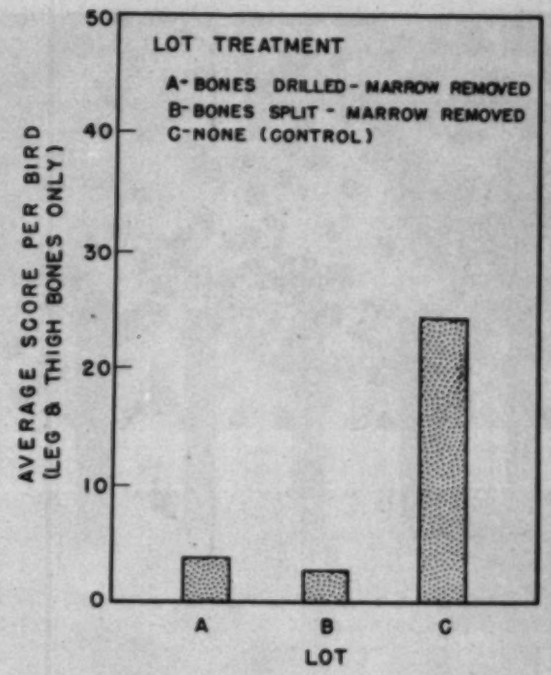

FIG. 6. The effect of removing the marrow prior to freezing on the bone discoloration in fryers.
(12-week-old New Hampshire fryers used.)

These results indicated that the bone marrow was the only source of the pigment causing discoloration since other sources, if they existed, would presumably still have been present. Evidence to support this conclusion was also indicated in Experiment IV when birds that were not bled prior to freezing did not show increased darkening. In that instance considerable quantities of blood were present in the blood vessels lying close to the leg and thigh bones but apparently did not contribute to darkening of the bones.

Freezing, Storing and Thawing. The results of Experiment VII involving various temperature and time factors in storage are shown in Figure 7. Statistical analysis did not show any significant differences among the temperatures used. Significant differences were found, however, among lots with varying storage time. These findings should be considered carefully. It will be noted in Figure 7 that the magnitude of the differ-

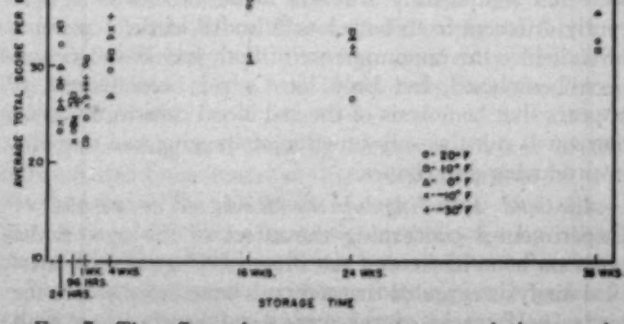

FIG. 7. The effect of storage temperature and time on the bone discoloration in frozen fryers.
(12-week-old New Hampshire fryers used.)

ences in bone color scores among the storage periods is not sufficiently great to be of any practical importance. Furthermore, there is no consistent tendency for bone darkening to increase or decrease with increased time of frozen storage. The variation in scores among the various storage periods appeared to result from the fact that the judges scored the bones from each storage period on a different day. The judges' levels of scoring were apparently not the same from day to day.

Experiment VII also yielded some information on the effect of freezing rate on bone darkening. At —30° F. the packaged birds were frozen in 4 hours; at 20° F. nearly 30 hours were required to freeze them. Since there were no significant differences among the scores, it was concluded that freezing rate (within the range studied) did not influence bone darkening.

The results of Experiment VII are at variance with those of Woodroof and Shelor *(13)*, who reported that frozen storage below —15° F. resulted in decreased bone darkening and storage above 10° F. resulted in increased bone darkening. They further reported that bone darkening was "slight" after one week of frozen storage, increased "markedly" up to four weeks, and continued to increase "slightly" during 26 weeks of storage.

The different storage temperatures employed in Experiment VIII did not result in increased bone darkening. The average total scores per bird in the control lots were 22.3 for the birds held at 20° F. and 23.9 for those held at —10° F. The three lots shifted alternately from one temperature to the other had average scores of 21.7, 24.5 and 21.8. None of these values differ significantly.

It was found in Experiment IX (Figure 8) that significantly lower bone color scores resulted if three conditions were fulfilled. First, it was necessary to freeze and store the birds at —30° F.; second, it was necessary to thaw the birds rapidly; and third, it was necessary to cook the birds immediately after rapid thawing. Rapid thawing could be accomplished by placing the birds in the oven without prior defrosting or by thawing them in running water at 140° F.

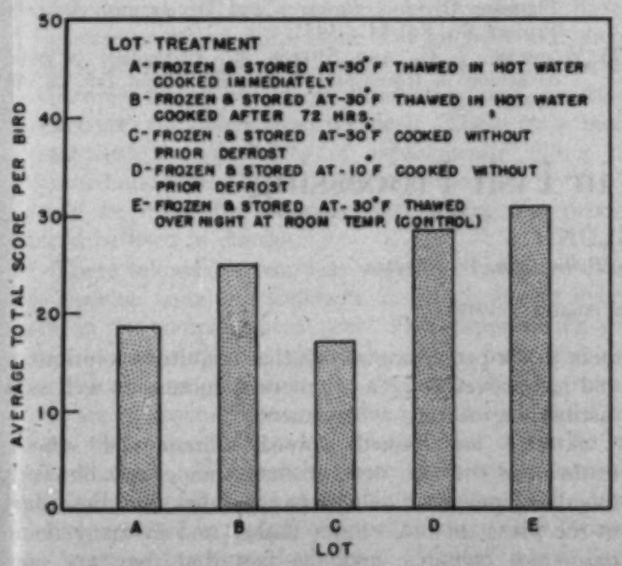
LOT TREATMENT
A- FROZEN & STORED AT -30° F THAWED IN HOT WATER COOKED IMMEDIATELY
B- FROZEN & STORED AT -30° F THAWED IN HOT WATER COOKED AFTER 72 HRS.
C- FROZEN & STORED AT -30° F COOKED WITHOUT PRIOR DEFROST
D- FROZEN & STORED AT -10° F COOKED WITHOUT PRIOR DEFROST
E- FROZEN & STORED AT -30° F THAWED OVER NIGHT AT ROOM TEMP. (CONTROL)
AVERAGE TOTAL SCORE PER BIRD
0
10
20
30
40
50
A
B
C
D
E
LOT

FIG. 8. The effect of various treatments prior to cooking fryers on the bone discoloration due to freezing.
(12-week-old New Hampshire fryers used.)

It was shown that freezing and storing the birds at —10° F. resulted in darkening bones even when the birds were placed in the oven to cook without prior defrosting (note lot D, Figure 8). Birds that had been frozen and stored at —30° F. and thawed in hot running water but held 72 hours at 35° F. before cooking had bones darkened nearly as much as the control (note lot B, Figure 8).

Cooking. In Experiment X it was found that the method of cooking did not greatly influence the bone color scores. Average total score per bird for simmering in water was 31.3, for roasting 35.5, and for frying 38.1. These average scores were not found to differ significantly. The results showed that the method of cooking used in the other experiments (roasting) was as effective in developing bone darkening as the more common method (frying) used on birds of this size. It was employed in most of our work because of convenience.

Precooking the birds (Experiment XI, Figure 9) for 30 or more minutes prior to freezing materially reduced the extent of bone darkening. Fifteen minutes of roasting at 300° F. prior to freezing was not effective in reducing bone darkening. Longer periods of precooking (i.e., 30, 45, and 60 minutes) gave bone-color scores which were significantly lower than the control. Woodroof and Shelor *(13)* reported that heating the pieces of chicken at 190° F. for 10 minutes prior to freezing reduced bone darkening but the flavor of the meat was impaired.

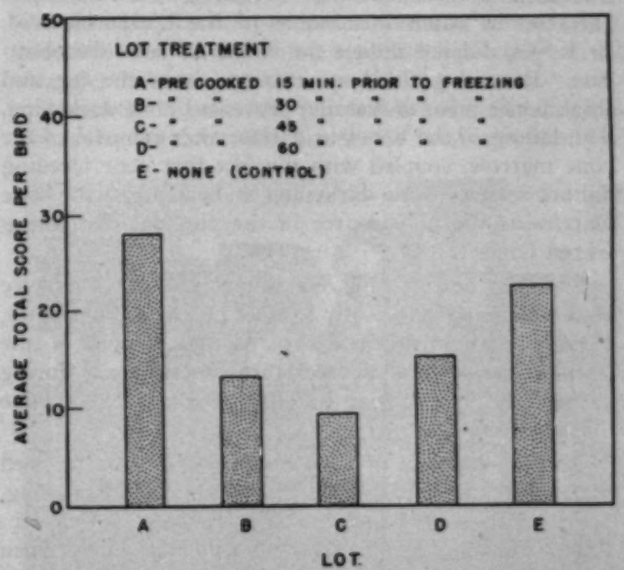

FIG. 9. Effect of pre-cooking prior to freezing on the bone discoloration in fryers.
(12-week-old New Hampshire fryers used.)

Summary

A study was made of the causes, occurrence, and prevention of bone darkening in frozen poultry. After freezing, storing, and thawing, the birds were cooked and the meat was removed from the bones. The extent of bone darkening was measured subjectively.

It was demonstrated that freezing and thawing hemolyze the red blood cells of the bone marrow. The hemoglobin thus liberated penetrates the walls of the bones and causes discoloration. However, when the bone-marrow erythrocytes were hemolyzed without freezing (by saponin), no darkening resulted. This indicated that freezing and thawing not only liberated the hemoglobin in the bone marrow but also made it possible for the pigment to penetrate the bone.

All bones of fryers were darkened somewhat by freezing and thawing; however the leg, thigh, and caracoid bones were the most seriously affected. Freezing and thawing did not darken any of the bones of yearling hens. Genetic background of the birds was not an important factor in bone darkening.

New Hampshires between the ages of 7 and 14 weeks did not differ significantly with respect to bone darkening. At the age of 16-17 weeks, however, bone discoloration was reduced.

The extent of bleeding, the degree of carcass separation, and the chilling method did not affect bone color. Refreezing defrosted stock was not found to produce increased bone darkening. Freezing the disjointed carcasses in water or solutions of NaCl, ascorbic acid, or KNO_3 did not reduce the extent of bone discoloration. Removing the bone marrow from the leg and thigh bones prior to freezing prevented bone darkening. The failure of the bones to darken after removal of the bone marrow, coupled with the fact that poor bleeding did not increase bone darkening, indicated that the bone marrow is the only source of the pigment discoloring frozen bones.

Freezing and storing conditions did not influence bone darkening sufficiently to be of practical importance. Freezing rate, temperature of storage, length of the storage period and temperature fluctuations during storage did not appear to effect the degree of bone discoloration.

The development of dark bones was greatly reduced by cooking the birds immediately after rapid thawing, provided they had been frozen and stored at —30° F. Rapid thawing did not reduce bone darkening when the birds had been frozen and stored at —10° F. or above nor when cooking was delayed for 72 hours after thawing.

Different methods of cooking (i.e., frying, boiling, and roasting) were not found to differ greatly with respect to the development of bone discoloration in frozen birds. However, roasting the pieces of chicken 30 minutes or more prior to freezing reduced bone discoloration significantly.

Acknowledgment

The studies reported herein were financed in part by a grant-in-aid from Safeway Shares, Inc.

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Engineering Advances in Fish Processing[a]

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(REVIEW PAPER)

An improved flavor, odor and appearance to canned salmon by removing skin and bone, accomplished with two new machines. Salmon leather a resulting by-product.

The assigned subject, "Engineering Advances in Fish Processing" is so large that, with the limited time available, it was thought best to describe one advancement in the processing of fish that is quite revolutionary and has proven to be a commercial success as well as a distinct engineering achievement.

Skinned and boned canned salmon and salmon leather are the two new products made possible with this development. Their preparation has been described in the press, in radio news flashes and in many home economics columns, and the fact that they are new products of improved quality has been stressed.

Canned salmon has been produced without any im-

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 11, 1949.

provement in product quality since the inception of the industry in 1864. Many important advances have been made in preparing the fish and increasing the speed of canning lines. Early procedures included hand butchering and hand filling in hand-made cans.

There is a long list of mechanical improvements which include the sanitary can, automatic filling machines and the "iron chink" or mechanical butchering machine which removes the head, tail, fins and viscera in one machine at speeds up to 72 fish per minute. The more recent improvements include filling, weighing and vacuum closing machines that operate at 240 cans per minute with the use of collapsed cans that are reformed and ends attached at the cannery simultaneously with the canning operation.

A distinct advancement was made in 1941 when the "Foonken Indexing Device," which indexes fish by pushing behind the gill-bone for exact beheading on the iron chink, was introduced. Previous to this, the indexing for beheading was done by eye with excellent results until long hours and fatigue were encountered.

The high speeds of salmon canning lines mean that 32 tons of raw fish are handled and canned with three lines in one hour, which rules out any extensive hand labor in Alaska canneries. The cost of common labor for actual canning time in Alaska includes transportation, food, housing, laundry and taxes, which brings the cost of labor to $13 per hour for white labor and $6 per hour for oriental labor in mid-Alaska areas.

The Pacific American Fisheries, Inc. decided to improve the quality of canned salmon, regardless of the serious and apparent obstacles. Several independent polls conducted with housewives indicated that skins and bones normally associated with canned salmon and other canned fish were not appetizing to the average consumer. Some of the replies received were suggestions for improving the product, while others were direct criticisms.

Preliminary packs of skinned and boned canned salmon produced in 1945 showed a distinct improvement in appearance and also a marked improvement in flavor. Separate packs of skins alone had an odor and flavor that is not associated with canned salmon. Bones canned separately tasted like chalk, illustrating that the flavor penetrates the bones from the flesh. These early packs illustrated the feasibility of mechanically filling the skinned and boned fillets. If suitable mechanical devices could be made for skinning and boning the process could be used in Alaska.

There followed a two-year period of extensive effort to develop suitable equipment, in which almost everyone in the company took part. Five experimental machines with different approaches were built and discarded as soon as tested. By the 1946 packing season one set of machines was installed at the Kasaan Cannery that netted 800 cases, adequate for a market research check. The results were sufficient to warrant the building of five sets of machines for the 1947 season, which resulted in a pack of approximately 60,000 cases.

A set of machines includes a "Boner" which cores out the backbone and splits the fish into two halves along the dorsal-ventral axis. The backbone is cored

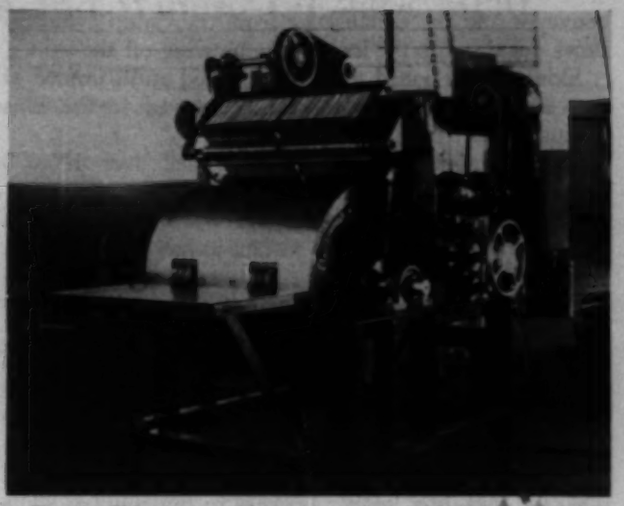

FIG. 1. Skinning machine—set up in machine shop for initial test before shipping to cannery.

out without any loss of flesh and is flumed to a disposal source through a pipe attached to the machine (Figure 2). The machine is unique in that the backbone is indexed on a rail and removes the entire backbone with close to 100% efficiency and can handle fish at speeds that will keep a one-half-pound line operating at 240 cans per minute.

From the "Boner" the two boned and split halves are conveyed mechanically to the "Skinning Machine"

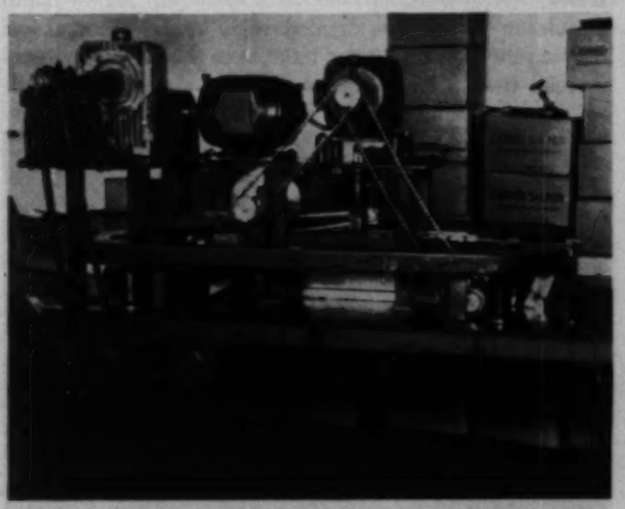

FIG. 2. Boning machine—ready for shipment to cannery.

(Figure 1). Essentially it holds the fish by the tail on a revolving drum, skin side down, and pulls the fish halves past a reciprocating knife set at skin thickness from the drum.

Protruding jaws during the feed cycle coupled with slots in the jaws, allow stationary projections attached to the feed table to hold the fish tail extended past the table ready for the pickup as the jaws close.

Compressed air operates the clamps and supplies adequate clamping pressures to hold the fish. As the fish approaches the knife the jaws recede below the drum surface so that it can pass under the knife edge. After the skinning operation the fish halves drop onto a

conveyor and the exhaust air from the clamp cylinders flows out through the lower jaw, blowing off the skin.

Skinned and boned flesh is inspected and trimmed of any adhering skin before it is conveyed to the bins behind the automatic filler.

The new process has produced well over 100,000 cases and is being well received by the consumer.

The loss due to skinning and boning varies from 9-12% depending upon the surface-volume relationship. Fat, well rounded fish have less surface per unit of weight than thin, flat fish, such as mature pinks.

The skins presented a problem of possible utilization. Excellent glue was made, but transportation costs and competitive animal hoofs and horns ruled this item out as a non-profitable item. Leather was another possible outlet. Extensive research on this item for over a year produced salmon leather of sufficient quality to interest one of the leading leather brokers in the country. The grain of the leather is beautiful and the scale pattern is non-uniform, making it almost impossible to duplicate on a platen die (Figures 3-5).

Salmon leather has been made in experimental batches for many years, but has not reached any commercial importance due to its roughness of surface. The leather that is now being marketed has had the scale pockets removed, as illustrated by the samples distributed. The resulting salmon leather is smooth and will not snag nylon hose. At present the salmon leather will be used for women's shoes in all popular color styles.

Salmon leather has created wide interest, but as yet only a few thousand hides have been produced for commercial use. If the interest in salmon leather and the orders for women's shoes are any criterion, it promises to be a competitor with lizard and cobra.

FIG. 3. Photomicrograph (67 x) cross-section of salmon leather illustrating fibre structure and top scale layer which is removed and shown as Fig. 5.

NOTE: The processes covered in this paper were developed in the Pacific American Fisheries Research Laboratory at Bellingham, Washington, with the following personnel actively engaged: G. A. Biery and G. E. Hube. R. W. Simmons was responsible for the leather development.

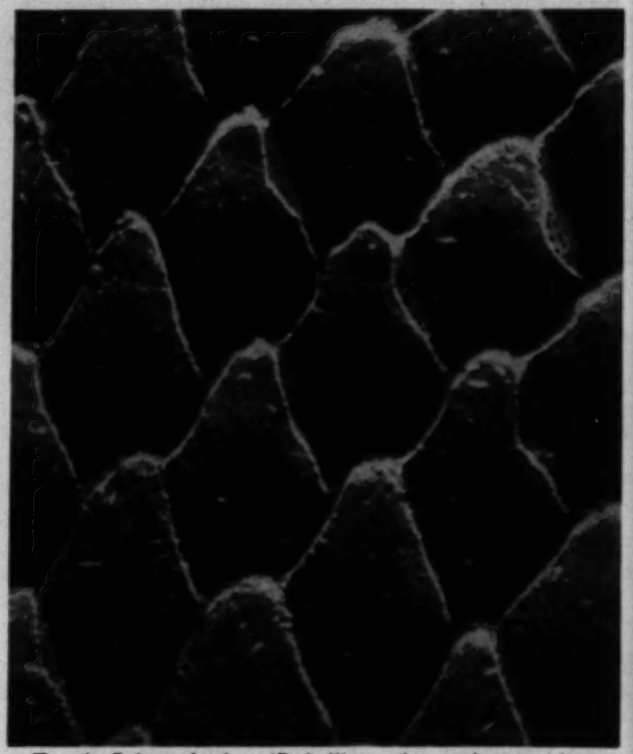

FIG. 4. Salmon leather (7 x) illustrating grain or scale pattern. Notice the lack of uniformity of adjacent parts.

FIG. 5. Bottom side of scale pockets which is discarded in salmon leather manufacture—5 x.

The Acids of California Grapes and Wines. I. Lactic Acid*

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The sources of lactic acid in wine and the methods for its determination are discussed. Most of the lactic acid appears to result from bacterial activity with malic acid as the primary substrate. However, tartaric acid destruction is not unknown. The amounts of lactic acid present in commercial California wines range from 0.07 to 0.49 percent. In small scale experimental fermentations, as much as .60 percent lactic acid has been found.

Wine like all fermented beverages contains a number of different organic acids. Some are present in the unfermented media from which the wine is produced; others are formed by yeast or bacteria during fermentation; and still others result from microbial activity in the finished product. The nature and quantity of acids present in the finished wine depend on all these sources. In addition, they may be greatly modified by such environmental factors as antiseptics and growth regulators. These acids have considerable influence on the keeping and organoleptic properties of wines.

This paper and succeeding ones will review the information available on organic acids in wines, particularly in those of California. Methods of controlling undesirable changes in the acid content in winery practice will also be suggested. Lactic acid has been selected as the first in the series because so very little information on its occurrence in California wines has been published. Cruess *(8)*, for example, quotes only the German literature on the subject and concluded that it was of little significance in our wines. European enologists, however, such as von der Heide *(17)*, Ribéreau-Gayon *(26)*, and Vogt *(32)*, have reported it to be of considerable importance in the aging of wines.

Lactic acid was not found in unfermented grape juice of sound fruit by von der Heide *(17)*. Vogt *(32)* found traces to 0.05 percent but his method of determining lactic acid has been criticized.

Small amounts of lactic acid are a by-product of alcoholic fermentation by yeasts. Hohl and Joslyn *(2)* have reviewed the literature on this source. Using a special nitrogen source they obtained a maximum quantity of 0.19 percent. However, in normal fermentation on grape media with six different yeasts they found from 0.08 to 0.13 percent with an average of 0.11. Génevois and Ribéreau-Gayon *(16)* reported somewhat smaller quantities, 0.045 to 0.09 percent, produced in the fermentation of sugar. [*See also:* Ribéreau-Gayon and Peynaud, *(28)*]. The range in lactic acid content from fermentation alone is thus not large.

Formation of lactic acid by microörganisms other than yeasts during alcoholic fermentation of grape musts is possible, but is normally unimportant because of (1), the selective action of the sulfur dioxide which is commonly added before fermentation (2), the addition and subsequent predominance of yeasts and their rapid fermentation of all, or nearly all, the sugar present and (3), the fact that grape juice, with its pH of 3.0 to 3.5, is a less favorable media for the growth of lactic acid-forming bacteria than it is for yeasts. Furthermore, the use of pure yeast cultures and moderate fermentation temperatures throughout the California industry have practically eliminated fermentations that cease with residual sugar (stuck fermentations). Occasionally, however, excessive lactic acid may develop before fermentation ends, presumably by bacterial action. For example, new dessert wines, Hillig *(19)*, contain greater quantities of lactic acid than would normally be formed as a by-product of yeast fermentation.

Several factors restrict the activity of microörganisms and thus the formation of lactic acid. These are the presence of sulfur dioxide, 10 or more percent alcohol, the absence of sugar, the relatively low pH, and cellar practices. Hickenbotham *(18)* notes that successive rackings in the presence of sulfur dioxide eliminate much of the population of microörganisms. Filtering and pasteurization also accomplish a like result, and, in some cases, lack of oxygen has a restrictive influence. Benvegnin, Capt, and Piguet *(4)* stress that the low temperature of storage cellars markedly inhibits the growth and activity of such organisms.

Normally, then, one would not expect the lactic acid content to rise after fermentation. That it does increase after fermentation is well-known. This result is largely due to bacterial action on malic acid, a normal constituent of grapes. The quantities of malic acid present in grapes is variable depending on the variety and the climate of the region of growth, Amerine and Winkler *(2)*. Several types of bacteria are able to form lactic acid from this source. [*See:* Anon., *(3)*; Benvegnin, Capt, and Piguet *(4)*; Kramer *(22)*; Ribéreau-Gayon *(26)*; and Suverkrop and Tchelistcheff *(30)*]. Malic acid is the substrate for their activity at first. The process is known as the malo-lactic fermentation. Later other carbon sources, such as tartaric acid and glycerine, may be utilized if the organisms are sufficiently numerous and active.

Unrestricted and continued microbial activity may lead to more profound chemical changes and disease. Under certain conditions the malo-lactic fermentation is encouraged as a means of reducing the malic acid content of too-acid wines. Only about two-thirds as much lactic acid is formed as the malic acid fermented. The malic acid is utilized according to the equation: $HOOC\ CH_2\ CHOH\ COOH = CO_2 + CH_3\ CHOH\ COOH$. Furthermore, lactic acid is a weaker acid than malic: $pK = 3.81$ versus a pK_1 of 3.46 for malic acid. Because of the high malic acid content of the northern

* Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 11, 1949.

TABLE 1

Lactic Acid Content of Wines

Author	Type of wine	Region	No. of Samples	Lactic acid, gms./100 ml.			Method used
				Maximum	Minimum	Average	
Fabre *(11)*	Dry red	Algeria	8	0.335	0.066	0.191	Bonifazi-F.
Hillig *(19)*	Various	New York	5	0.35	0.11	0.24	Hillig
Hillig *(19)*	Various	California	12	0.49	0.19	0.30	Hillig
Hugues *(21)*	Dry red	Midi	40	0.336	0.064	0.135	Bonifazi
Hugues *(21)*	Spoiled	Midi	20	0.370	0.120	0.226	Bonifazi
Kunz *(23)*	White	Austria	16	0.734	0.119	0.340	Kunz
Kunz *(23)*	Dry red	Austria	6	0.334	0.225	0.294	Kunz
Ribéreau-Gayon *(27)*	D. white	Bordeaux	28	0.245	0.036	0.104	Espil
Ribéreau-Gayon *(27)*	Dry red [b]	Bordeaux	7	0.107	0.058	0.077	Espil
Ribéreau-Gayon *(27)*	Dry red [c]	Bordeaux	24	0.382	0.131	0.232	Espil
Roettgen *(29)*	D. white	Germany	19	0.56	0.10	0.43	Kunz
Suverkrop *(30)*	Dry red	California	5	0.31	0.18	0.24	Möslinger

[b] Less than one year old. [c] Over one year old.

European wines, this fermentation was first studied in Austria and Germany. Vogt *(32)* has reviewed the information on its occurrence and control in Austria and Germany, while Benvegnin, Capt, and Piguet *(4)* have done the same for Switzerland. In these cases primarily white wines were involved. In France, Ferré *(12)* studied the process in Burgundy, and Ribéreau-Gayon and Peynaud *(27)* at Bordeaux. Garina-Canina *(15)* has summarized the Italian work. Suverkrop and Tchelistcheff *(30)* have reported on its occurrence and control in the dry red table wines of the Napa Valley in California.

As a result of the processes outlined above, varying quantities of lactic acid are found in the finished wine. Since the voluminous European literature has been summarized by Fresenius and Grünhut *(13)*, von der Heide *(17)*; Kramer *(22)*, Ribéreau-Gayon and Peynaud *(27)* and others, it will not be reviewed here. The lactic acid contents of wines have been summarized as follows [Anon. *(3)*]: (1) Wines having less than 0.2 percent lactic acid and 0.1 percent of volatile acidity are those in which little or no secondary fermentation of malic acid by bacteria has occurred. (2) Wines having over 0.2 percent lactic acid but less than 0.1 percent of volatile acidity are sound wines that have undergone a malo-lactic fermentation. (3) Wines with over 0.2 percent lactic acid and over 0.15 percent volatile acidity are diseased wines which have undergone mannitic, lactic, or other bacterial spoilage. Brémond *(6)* and Fabre and Brémond *(11)* make a slightly different classification. (1) Wines containing less than 0.20 percent lactic acid and less than 0.123 percent acetic acid are considered to be sound young wines; their lactic acid-malic acid ratio is below 1. (2) Wines with a lactic acid content of 0.215 to 0.310 percent and with a lactic acid-malic acid ratio above 1 are considered wines undergoing or having finished with a malo-lactic fermentation. (3) Finally, wines with 0.30 to 1.25 percent lactic acid and a lactic acid-malic acid ratio of more than 1 are also classed as wines in which microbial activity has occurred. If the volatile acidity has increased to more than 0.122 percent, the fermentation is considered undesirable. The only published data on the lactic acid content of California wines appears to be that of Hillig *(19)* and of Suverdrop and Tchelistcheff *(30)*. Their data, together with those for European wines, are summarized in Table 1.

The evolution methods for the determination of lactic acid in wines have been reviewed by McNair *(24)*. Although a surprisingly large number of methods have been tried, most of them have been discarded. Those currently in use (Table 2) are based on (1) the separation of barium lactate from other barium salts by virtue of its solubility in 70 percent alcohol—Möslinger, Bonifazi, Michel, Kunz—(2) the oxidation of lactic acid to acetaldehyde by dilute permanganate in acid solution—Friedmann, Espil—and (3) the colorimetric determination of ferric chloride-lactic acid color — Hillig's procedure.

TABLE 2

Methods for the Determination of Lactic Acid

Method	Ether Extraction	Volatile Acids steam distilled	Barium Lactate separated in 70% alcohol	Determined by
Möslinger *(24)*	No	Yes	Yes	Alkalinity of ash
M. Möslinger *(24)*	No	Yes	Yes	Alkalinity of ash [d]
Bonifazi *(5)*	No	No	Yes	Alkalinity of ash —volatile acids
M. Michel *(25)*	No	No	Yes	Alkalinity of ash —volatile acids [e]
Kunz *(24)*	Yes	Yes	Yes	$BaSO_4$ of alkalinity of ash
Friedmann *(14)*	Yes	No	No	$KMnO_4$ oxidation
Espil *(9, 10)*	No	No	No	$KMnO_4$ oxidation
Hillig *(19)*	Yes	No	No	Color with $FeCl_3$

[d] Uses $BaCO_3$ instead of $Ba(OH)_2$. Ashing procedure specified.
[e] Removes any excess $Ba(OH)_2$ with CO_2. Adds K_2SO_4 before ashing.

Solubility of barium lactate in 70 percent alcohol has been the basis of the Kunz and Möslinger procedures, both of which have been in popular use. The essential feature of the Kunz method is the extraction of lactic acid by ether. The volatile acids are removed next by steam distillation and the barium lactate is separated in 70 percent alcohol. The procedure is tedious but accurate. In the Möslinger technique the other extraction is omitted. Several modifications of the Möslinger procedure have been summarized by McNair *(24)*. He failed to note, however, the slight but significant changes made in Bonifazi's *(5)* procedure by Ferré *(12)* and by Michel *(25)*. Michel removed the excess barium with carbon dioxide and potassium sulfate. The specificity of the Möslinger method has been criticized by Ventre *(31)* as giving high results. Roettgen *(29)*, however, found an average lactic acid content of 0.42 percent in 19 wines by this method and of 0.43 percent by the Kunz technique, the figures thus indicating no appreciable

difference. It should be noted, in passing, that while the Möslinger technique is not adapted to sweet wines, ether-extraction procedures may be used on them *(23)*.

The Friedmann and Graeser *(14)* method of oxidation by permanganate is commonly used in this country. A similar procedure was suggested by Espil *(9, 10)* and was used by Ribéreau-Gayon and Peynaud *(27, 28)*. Espil uses the Jaulmes and Espezel buffers and these are preferred as the end point is not so likely to fade. Cooling the distillates, as outlined by Friedmann and Graeser, has been advantageous at Davis during warm weather even when using the Jaulmes and Espezel buffers. Although the oxidation procedure is commonly said to be more specific than methods based on barium solubility, it is difficult to see why this is so. Permanganate-oxidizable substances that yield acetaldehyde no doubt escape the clarification procedure.

The "official method" of the Association of Official Agricultural Chemists, Hillig *(19)*, is based upon the color reaction of ferric chloride and lactic acid. Claborn and Patterson *(7)* have developed a method for determining and identifying lactic acid in foods. It is based on partition chromatography following ether extraction and separation of lactic from succinic acid by means of its solubility in 70 percent alcohol. This procedure has, thus far, not been applied to wines, and it appears to be too lengthy for routine analyses.

Experimental Results

In order to compare the various methods of determining lactic acid an artificial wine was made: alcohol, 12.0; potassium acid tartrate, 0.30; malic acid, 0.10; succinic acid, 0.10; acetic acid, 0.10; glycerin, 1.00; and dextrose, 0.20.

Eight tests, with duplicate analyses of each, were made using four methods—Bonifazi, modified Möslinger, Möslinger, and Espil (Table 3). The results from duplicate tests were satisfactory with the exception of one Möslinger determination. The Bonifazi method, however, gave high results.

TABLE 3

Recovery of Lactic Acid from Artificial Wine

Method	Percent lactic			
	Present	Found	Present	Found
Bonifazi	0.00	0.001, 0.002	0.103	0.111, 0.113
M. Möslinger	0.00	0.006, 0.007	0.103	0.107, 0.105
Möslinger	0.00	0.007, 0.005	0.103	0.101, 0.121
Espil	0.00	0.001, 0.002	0.103	0.105, 0.105

Six commercial California wines were used for a further comparison of the Espil, Bonifazi, modified Möslinger, and Kunz methods (Table 4). The Bonifazi method gave higher results than the Espil in three cases and less in two. The modified Möslinger and Kunz methods gave approximately the same results as the Espil. There is little evidence here that the permanganate-oxidation procedure is any more or less specific than the lactate-solubility methods.

For routine work with dry wines, the Friedmann-Graeser or Espil oxidation techniques give comparable results. The clarification procedure, however, is not satisfactory with sweet wines, high results being frequently obtained. Extraction, as proposed by Kunz *(23)* or used in Hillig's *(19)* procedure, will eliminate this objection. Most of the determinations reported herein have been made with the permanganate oxidation procedure, but the distillations have not been as rapid as reported by Ribéreau-Gayon and Peynaud or by Friedmann and Graeser. Thirty to forty minutes are required for the oxidation using N/200 permanganate. Low results are sometimes obtained by more rapid oxidation, even though manganous sulfate is used as a catalyst.

TABLE 4

Comparison of Lactic Acid Methods on California Wines

grams/100 ml.

Type of Wine	Method			
	Espil	Bonifazi	M. Möslinger	Kunz
Zinfandel	0.23	0.28	0.25	0.20
Claret	.25	.31	.29	.24
Burgundy	.17	.15	.18	—
Grignolino	.18	.19	.19	.16
Sauterne	.26	.26	.23	—
Dry Sauterne	0.18	0.16	0.16	0.19

Several studies were made with Hillig's *(19)* procedure, the directions for which were followed implicitly. With the Coleman spectrophotometer a transmission curve comparable to Hillig's was obtained for the lactic acid-ferric chloride color when a sufficient depth was used. With moderate amounts (8-12 mgms.) of lactic acid and 40 mm. cells, a standard curve suitable for analytical use was prepared. With smaller cells and lesser quantities anomalous curves were obtained. Stray light which caused the fading of the small amount of color present probably accounted for this. The primary disadvantage of the method is the light sensitivity of the color compound. Painting the colorimeter cells black may overcome this. However, the method also requires careful weighing of a special charcoal for clarification. Some of the fluctuations in transmission curves may be due to variations in the use of this charcoal.

Because the amounts present in California white wines were believed to be low, a series of commercial dry, or nearly dry, white table wines (Sauterne) were analyzed by the Espil procedure (Table 5). The range for the 15 wines was from 0.080 to 0.426 per cent, averaging 0.188. In some cases, significant amounts of malic

TABLE 5

Lactic, Tartaric and Fixed Acid Content of California Sauterne Wines

grams/100 ml.

No.	Lactic	Tartaric	Fixed Acid	pH	Sugar
1	0.426	0.094	0.44	3.61	1.10
2	.252	.162	.47	3.62	0.13
3	.129	.108	.40	3.50	.20
4	.198	.161	.52	3.54	.21
5	.253	.084	.40	3.90	.11
6	.173	—	.53	3.55	.30
7	.099	.169	.56	3.48	.21
8	.129	.108	.48	3.29	.26
9	.160	.157	.49	3.53	.80
10	.150	.063	.44	3.80	.17
11	.120	.162	.68	3.19	.13
12	.270	.063	.48	3.62	.34
13	.080	.106	.50	3.45	.17
14	.180	.156	.43	3.60	.18
15	0.210	0.106	0.57	3.57	0.19

acid may have remained, as the sum of the lactic acid and tartaric acid did not equal the fixed acidity. Succinic acid was also present, of course, and moreover, considerable citric acid may have been used in finishing the wines. The average quantity of lactic acid in these wines was nearly double that which would be expected from fermentation alone and indicated that formation of lactic acid after fermentation is by no means negligible in white California table wines, in spite of the very general and frequently excessive use of sulfur dioxide. This finding is in agreement with Suverkrop and Tchelistcheff's *(30)* observation that some of the bacteria involved in the malo-lactic fermentation are very tolerant of sulfur dioxide. The lactic acid content of other commercial California wines is given in Table 4. Using the Espil figures, these results range from 0.17 to 0.26 percent and indicate that the six red table wines contained no more lactic acid than the whites.

Typical changes in lactic, malic, and tartaric acids in experimental varietal lots of wines were observed during 15 months' storage (Table 6). The wines were fermented in October 1947, stored in five and ten gallon wooden containers. The white wines were kept at 11.63° C. (53° F.) and the reds at 15.56° C. (60° F.). When the wines were racked and analyzed in December and January following the vintage significant amounts of lactic acid were found in three of the five wines. The wines were racked again in the spring and bottled during the summer and fall. No sulfur dioxide was added after fermentation. The cellar temperatures were constant during the storage period. The racking and handling was carefully done so that gross contamination did not occur. In spite of these precautions, however, very significant increases in lactic acid took place during the storage period. Samples 1 and 4, originally low in lactic acid, showed marked increases in it and decreases in malic acid. The tartaric acid in number 1 was also attacked, and the wine was definitely spoiled. In sample 3, more than half the original tartaric acid disappeared in spite of the 12.2 percent alcohol in the wine. Since the excess tartrate had been removed by storage at 10° C. (50° F.) prior to aging it is evident that tartaric-acid-destroying organisms do occur in California wines. Fabre and Brémond's *(11)* classification of wines with over 0.3 percent lactic acid as spoiled apparently does not apply to California wines, as the second dry white sample was sound organoleptically although it had 0.348 percent lactic acid. Much more information is needed, particularly on commercial wines, to establish the permissible range in lactic acid content.

In a further study, 28 of the 1948 experimental wines were analyzed. Most of these were of the Pinot family of grapes which are very low in acid and high in pH and which have a marked tendency to acid reduction, Amerine *(1)*. Ten of these analyses, summarized in Table 7, show the lactic, tartaric, and malic acid contents in December, 1948 and in July, 1949. Of the 28 samples tested in December, 11 had 0.14 percent lactic acid or less, while 3 had over 0.3 percent. Since the 1948 season was very cool, the grapes retained a high malic acid content and the alcohol content was frequently low. These factors partially explain why high lactic acid could occur with high residual malic acid. In two other cases, not recorded in the table, the lactic acid content after fermentation was 0.43 and 0.65 percent. These high quantities probably resulted from lactic acid fermentation of sugar.

Control of the malo-lactic fermentation is thus obviously important in California. Although it offers a means of legally reducing excess acidity with varieties of very high total acidity in certain regions and seasons, it should not be allowed to occur in wines of low acidity. The fairly high lactic acid content of some California dry white wines is an illustration. Ventre *(31)* has warned that a malo-lactic fermentation in wines of low acidity is "disastrous" to their quality.

TABLE 6

Changes in Acids During First 15 Months of Storage

gms./100 ml.

Type	January, 1948			February, 1949				
	Lactic	Tartaric	Malic	Lactic	Tartaric	Malic	Alcohol	Condition
Dry red	0.191	0.153	0.290	0.485	0.028	0.027	11.0	Spoiled
Dry red	0.384	0.182	0.290	0.364	0.194	0.164	11.1	Acetified
Dry red	0.228	0.180	0.030	0.408	0.070	0.059	12.2	Spoiled
Dry white	0.094	0.237	0.246	0.230	0.215	0.068	15.4	Sound
Dry white	0.229	0.196	—	0.348	0.186	0.099	12.0	Sound

TABLE 7

Changes in Acids During the First Nine Months of Storage

gms./100 ml.

	December, 1948				July, 1949				pH
	Lactic	Tartaric	Malic	Acetic	Lactic	Tartaric	Malic	Acetic	
1	0.251	0.267	0.126	0.083	0.326	0.234	0.121	0.154	3.53
2	.204	.262	.170	.069	.286	.236	.115	.133	3.51
3	.338	.199	.109	.118	.561	.029	.102	.218	4.02
4	.231	.154	.280	.116	.596	.120	.122	.208	4.15
5	.234	.273	.240	.034	.247	.212	.134	.044	3.69
6	.069	.413	—	.034	.097	.370	.476	0.46	3.08
7	.133	.494	—	.108	.162	.412	.164	.110	3.39
8	.282	.305	.214	.095	.435	.229	.105	.149	3.41
9	.046	.370	.202	.039	.186	.337	.252	.051	3.31
10	0.157	0.168	0.117	0.037	0.317	0.157	.097	0.054	3.89

Some of the measures, besides pasteurization, recommended to prevent an excessive malo-lactic fermentation are: (1) keep the free-run juice separate from the press-juice, (2) prevent aeration during fermentation, (3) rack early, (4) store at low temperature, (5) fine early, (6) filter closely, and (7) use moderate amounts of sulfur dioxide. On small-scale lots at Davis, these measures have not always proved effective. Garina-Canina *(15)* has listed high tartaric acid and high tannin content as having an inhibitory influence. Kramer *(22)* has discussed the possibility that bacterial decomposition of the lactic acid present may eventually occur. More work needs to be done in this field.

Summary

Several methods for the determination of lactic acid in wines are available. Both the Friedmann-Graeser and Espil procedures give consistent results when care is taken in the oxidation and distillation. Michel's modification of the Möslinger procedure seems better than the original Möslinger procedure or Bonifazi's adaptation. Hillig's technique gives usable absorption curves but requires careful control to prevent fading of the color and to employ comparable quantities of lactic acid in the known and unknown. The Kunz method is satisfactory but is very laborious and is subject to manipulative errors.

Few analyses of lactic acid in Calfiornia wines are reported in the literature. The 17 previously reported values ranged from 0.18 to 0.49 percent, averaging 0.29. In this study, 17 commercial California white table wines had a range of 0.07 to 0.43 percent, averaging 0.19. In 5 dry red table wines, the range was 0.17 to 0.26 percent, averaging 0.21. In ten 1948 wines made at Davis, the lactic acid content varied from 0.046 to 0.338 percent immediately after fermentation and from 0.047 to 0.596 eight months later.

Formation of large quantities of lactic acid in wines during or immediately after the primary fermentation has been observed in small scale lots. During storage, formation of lactic acid was accompanied by the disappearance of malic acid. Tartaric acid fermentation was also observed in two spoiled wines. In 7 of the 10 Davis wines lactic acid was the predominant acid present.

Control of malo-lactic fermentation in California appears to be more important than in Europe. Here the pH is already high and the acidity is frequently too low for good organoleptic quality. Measures to prevent a malo-lactic fermentation should normally be taken.

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Salt Tolerance in the Genus Aerobacter

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A group of salt-tolerant coliform bacteria tentatively identified as an unusually salt-tolerant type of the species Aerobacter aerogenes were found to tolerate up to 14.5% sodium chloride (grams NaCl per 100 ml.). These bacteria were isolated only from olive brines. Their salt tolerance was found to be adaptive in nature as cultures which were resistant or sensitive to sodium chloride could be prepared at will. Nevertheless these strains were more tolerant to salt, with or without adaptation, than other species of Aerobacter or Escherichia which were tested.

I. Introduction

In the literature on the adaptation of *Escherichia coli* and various pathogenic *Enterobacteriaceae* to a variety of chemical and physical conditions of environment, common salt (sodium chloride) is one of those chemicals found to have been investigated in some detail. Most of this accumulation of knowledge has been reviewed by Buchanan and Fulmer *(3)*, Kluyver and Baars *(13)*, Borman *(2)*, Hof *(9)*, Vaas *(24)*, Doudoroff *(4)*, and Severens and Tanner *(19)*.

In contrast there is but little knowledge of the salt tolerance of species of *Aerobacter* in spite of the fact that these bacteria cause most of the gassy spoilage of salted foods. Furthermore, most of the few recorded investigations involving *Aerobacter* were not concerned with a study of salt tolerance *per se* but with characterization of coliform bacteria responsible for gaseous spoilage of cucumbers and olives. See Tracy *(23)*; Etchells, Fabian and Jones *(7)*; and West, Gililland and Vaughn *(29)*. Although it might be assumed, on the basis of the close similarity between the two, that *Aerobacter aerogenes* would respond the same as *Escherichia coli* to salt, to the writers' knowledge, no direct comparison of the relative salt tolerance of the two species has been made. Furthermore, no serious attempt has been made to evaluate the salt tolerance of a significant number of cultures of *Aerobacter aerogenes* and *Aerobacter cloacae* or the salt tolerance of the coliform group[a] as a whole. Too, the question of whether salt tolerance of the coliform bacteria is the result of temporary adaptation or mutation is disputable. There is complete lack of knowledge concerning the highest concentration of salt that can be tolerated by the *Aerobacter* group. The possibility of using differences in salt tolerance as an aid in isolating and differentiating various species of *Aerobacter* has not been exploited. For these reasons investigations were conducted to determine, if possible, the relative sodium chloride tolerance of different species of *Aerobacter;* the inherent or acquired nature of the tolerance to salt; the transmissibility of the tolerance from culture to culture; and the limiting concentration of sodium chloride for growth of species of *Aerobacter*.

[a] As used herein the coliform group refers to bacteria of the genera *Escherichia* and *Aerobacter*.

II. Experimental

A. Methods

Samples used for isolation of representative coliform bacteria for the salt tolerance experiments included fermenting brines from cucumbers and olives. All samples were cultured in duplicate. One aliquot was plated directly into Levine's eosine methylene blue agar; the other was enriched in glucose or lactose broth which contained 10 percent salt (grams NaCl per 100 ml. of sample) prior to plating. One ml. of sample appropriately diluted was used for direct plating. Portions of 1 to 5 ml. of sample were enriched in the salted glucose or lactose broth for 24 to 72 hours depending upon the time required for production of gas in Durham tubes by positive samples. Cultures were obtained from positive enrichment samples by streaking them on Levine's E. M. B. agar. Well-isolated colonies from both the enrichment and direct plate samples were purified by repeated plating on E. M. B. agar. Stock cultures were maintained in duplicate. One set was carried on fresh water nutrient agar slants; the other on nutrient agar slants with 6 percent salt. An incubation temperature of 30° C. was used throughout unless otherwise specified.

The basal medium used for enrichment and for the various tests of salt tolerance contained 10 grams of proteose-peptone, Difco; 3 grams of Bacto-beef extract; 5 grams of glucose or lactose and 10 ml. of Andrade's indicator per liter. This basal medium was chosen because it promoted the growth of the *Aerobacter* group in the presence of salt better than any other medium tested. The medium was always adjusted to a pH value of approximately 7 because the work of Doudoroff *(4)* and independent investigations of the authors indicated that in the presence of high concentrations of salt a neutral reaction was desirable to reduce the additional burden of an unfavorable H^+ ion concentration. The concentration of salt in the medium was determined by titration with silver nitrate. To avoid errors resulting from concentration in the autoclave all salt determinations were made after the medium had been sterilized at 15 pounds pressure for 20 minutes and then cooled to room temperature.

B. Differentiation of the Bacteria

Generic and specific differentiation of the coliform bacteria isolated from the brine samples was made according to the methods suggested by Levine *(14)*, Levine et al. *(16)*, and Vaughn and Levine *(25)*. The Voges-Proskauer and Koser's citrate tests were used for primary differentiation. The V.-P. reaction was determined by use of the modified Barritt *(1)* reagent described by Vaughn et al. *(27)*. Separation of species was accomplished by determining the ability of the cultures to produce hydrogen sulfide and indole from suit-

able substrates, to cause liquefaction of gelatine, and to ferment starch, aesculin, salicin and glycerol.

Thirty-three of the 85 cultures isolated from the brine samples were obtained by direct plating. The remaining 52 isolates were recovered from enrichment cultures able to grow and ferment glucose or lactose in the presence of approximately 10 percent salt. The cultures were typical coliform bacteria in that they all fermented lactose; were short, gram-negative rods; did not form endospores; were motile and possessed peritrichous flagella. The differential characteristics of the bacteria are shown in Table 1.

TABLE 1

Suggested differentiation of the bacteria

Character	Method of isolation			
	Direct plating			Enrichment
	27 strains	3 strains	3 strains	52 strains
	Number of cultures showing positive reactions (30° C.)			
Voges-Proskauer reaction	27	3	0	52
Utilization of citrate	27	3	3	52
Methyl red test	0	0	3	0
Indole formation	19	0	0	0
H_2S production	0	0	0	0
Gelatine liquefaction	0	3	0	0
Fermentation of:				
Lactose	27	3	3	52
Starch	27	0	0	52
Aesculin	27	3	3	52
Salicin	27	3	3	52
Glycerol	27	0	3	52
Suggested species allocation	*Aerobacter aerogenes*	*Aerobacter cloacae*	*Escherichia intermedium*	*Aerobacter aerogenes*

The thirty-three cultures obtained by direct plating of the brine samples were represented by 27 strains of *Aerobacter aerogenes*, 3 strains of *Aerobacter cloacae* and 3 strains of *Escherichia intermedium;* all quite typical of the predominating coliform bacteria previously recovered *(29)* from such an environment.

In contrast, all cultures obtained by enrichment in the presence of salt were allocated to the species *Aerobacter aerogenes*. All of these latter cultures, isolated from different brines, appeared to be identical strains whose manner of growth on Levine's E. M. B. agar and resistance to salt strikingly separated them from the common types of coliform bacteria. Their difference in appearance on E. M. B. agar is noteworthy. On this medium the colonies are smooth, circular, slightly raised, flat-surfaced, average 4 to 5 mm. in diameter (48 hours at 30° C.) and show a tendency for neighboring colonies to coalesce. When examined without recourse to color standards the colonies would be called reddish purple in reflected light and grayish pink in transmitted light. Visual comparison of the colonies in reflected light with the standards of Maerz and Paul *(17)* showed the centers to correspond to the color K7, plate 44; the areas immediately surrounding the centers to correspond to the color between K5 and K6, plate 44; and the color of the peripheries to correspond to F3, plate 44. In transmitted light the color of all colonies correspond to B1, plate 44. All colonies of all cultures appeared to be identical or so nearly so that visual differences in color were not detected. Although the colonies grown on E. M. B. agar differ from any previously described by Levine *(15)*, or Epstein *(6)*, they do resemble the one colony type described by Vaughn and Levine *(25)* for *Escherichia intermedium*.

C. The Relative Salt Tolerance of Coliform Bacteria

As already emphasized, there is some contradiction concerning the highest salt concentration that can be tolerated by *Escherichia coli*. Although Visir *(28)* claimed that the coli organism could still grow in media containing 15 percent salt, the majority of investigators including Stadler *(21)*, Pettersson *(18)*, Karaffa-Korbutt *(12)*, Eisenberg *(5)*, Hotchkiss *(10)*, Tattevin *(22)*, and Doudoroff *(4)* found the highest endurable concentration to vary between 5 and 8 percent sodium chloride. Furthermore, there is relatively little information concerning the salt tolerance of other coliform species. However, it is evident from a study of the literature that all or nearly all coliform bacteria can grow in media containing at least 6 percent sodium chloride upon direct transfer from fresh water media. Therefore, it was desirable to test acclimatized as well as unacclimatized cultures for their resistance to salt in order to properly evaluate the relative tolerance of the cultures obtained from the brines.

a) *The Salt Tolerance of Acclimatized Cultures.* Acclimatized cultures were prepared by transfer of a small portion (about 0.04 ml.) of actively growing fresh water glucosce broth culture to basal glucose broth which contained 6 percent salt. After 48 hours' incubation at 30° C. the cultures were transferred to more of the glucose-salt medium. When the fifth transfers in 6 percent salt medium were growing vigorously (10 days after the start of the 5 serial transfers in the 6 percent salt broth), the cultures were inoculated into glucose broth containing 7 percent salt. The salt content was increased by approximately 1 percent increments every 48 hours as the cultures were transferred to new broth containing more and more salt until their growth was markedly retarded. When this point was reached each culture was transferred twice, at four day intervals, to the broth containing the same concentration of salt before testing its ability to grow in the presence of more salt. After retardation the increase in salt was limited to approximately 0.5 percent with each culture until no growth was observed after 4 days at 30° C.

The salt concentration which prevented growth of the acclimatized cultures is shown in Table 2. It is evident that the strains of *Aerobacter aerogenes* isolated after enrichment in the presence of salt have a greater resistance to salt than any of the cultures isolated by direct plating in a salt-free medium. It is also apparent that the majority of the cultures of *Aerobacter* as well as those of *Escherichia intermedium* can endure more salt than the control culture of *Escherichia coli*.

b) *The Salt Tolerance of Unacclimatized Cultures.* The effects of any previous contact with a concentrated saline environment were eliminated as much as possible by serial transfer of all of the cultures in fresh water glucose broth. The cultures were carried through 10 daily transfers to new tubes of this saltless medium. Then the cultures were tested for their resistance to salt contained in the basal glucose broth in concentra-

TABLE 2

The relative salt tolerance of acclimatized and unacclimatized coliform bacteria at 30° C.

Concentration of NaCl percent (gms. per 100 ml. of medium)	Brine cultures								Controls			
	Enrichment		Direct plating									
	Aerobacter aerogenes		*Aerobacter aerogenes*		*Aerobacter cloacae*		*Escherichia intermedium*		*Aerobacter aerogenes*		*Escherichia coli*	
	52 strains		27 strains		3 strains		3 strains		1 strain		1 strain	
	Number of cultures showing growth											
	A[b]	U	A	U	A	U	A	U	A	U	A	U
6.0	52		27		3		3		1		1	
6.5	52	52	27	26	3	3	3	3	1	1	1	1
7.0	52	52	26	15	3	3	3	1	1	1	1	0
7.5	52	52	14	12	3	2	3	2	1	0	1	0
8.0	52	49	12	0	3	3	3	0	1	0	0	0
8.5	52	49	2	0	2	1	2	0	0	0	0	0
9.0	52	45	0	0	1	0	2	0	0	0	0	0
9.5	51	15	0	0	1	0	0	0	0	0	0	0
10.0	50	0	0	0	0	0	0	0	0	0	0	0
10.5	36											
11.0	36											
11.5	36											
12.0	35											
12.5	35											
13.0	35											
13.5	29											
14.0	29											
14.5	29											
15.0	0											

[b] A and U show tests made with acclimatized and unacclimatized cultures, respectively. Blank space indicates no culture was grown.

tions varying between 6.5 to 10.0 percent, increased by 0.5 percent increments. One loopful (approximately 0.04 ml. portion) of fresh water glucose broth culture was used to inoculate each tube of test medium. The test media were then incubated at 30° C. for 10 days before examination for evidence of growth. The results of this experiment also are shown in Table 2. The results indicate that the ability of the cultures to grow in the presence of high concentrations of salt is acquired during a period of gradual training. It is quite clear, as previously shown by Doudoroff *(4)* with cultures of *Escherichia coli*, that the previous history of the culture has a marked effect on its ability to grow in the presence of large amounts of sodium chloride.

c) *The Effect of Size of Inoculum.* Eisenberg *(5)* and Slemmons *(20)* have shown that the larger the number of cells of *Escherichia coli* used in the inoculum on sudden transfer of cultures from fresh water to saline media, the greater the increase in the number which would reproduce. An experiment was made to test this observation on the effect of the size of the inoculum and at the same time provide further confirmation for the previous experiment on the tolerance of unacclimatized cultures.

Ten unacclimatized cultures were used; three cultures of *Aerobacter aerogenes* (enrichment) which had tolerated 12.5 percent salt; three cultures of *Aerobacter aerogenes* (direct plating) which had tolerated 9.0 percent salt; one culture of *Aerobacter cloacae* which had tolerated 10.0 percent salt; one culture of *Escherichia intermedium* which had tolerated 9.5 percent salt; and one culture each of *Aerobacter aerogenes* and *Escherichia coli* which were used as controls. The two latter cultures had never been in an appreciably saline environment since isolation in 1943. The eight cultures isolated from brines had been kept actively growing in fresh water media for 20 days. The ten cultures were transferred to fresh water glucose broth, incubated for 24 hours at 30° C., and then used for inoculation in portions of 1 loopful (approximately 0.04 ml.), 0.1 ml., 0.5 ml. and 1.0 ml. Inoculations were made in quadruplicate into 25 ml. of standard glucose-salt medium contained in 25 x 200 mm. test tubes. The concentration of salt was varied according to the tolerance of the test cultures and was carefully adjusted to compensate for the 0.5 and 1.0 ml. portions of salt-free inoculum. The inoculated media were incubated at 30° C. for one week. Criteria for growth included marked increase in turbidity in the test media when compared with suitable controls. It is evident from the data shown in Table 3 that the size of the inoculum does influence the ability of coliform bacteria to tolerate higher concentrations of salt.

d) *The Effect of Sudden, Large Increases in Sodium Chloride.* It was observed repeatedly during the preceding studies that the cultures of *Aerobacter aerogenes* isolated after preliminary enrichment in strong saline broth had a significantly greater tolerance to salt than the other coliform cultures tested. Doudoroff *(4)* found that sudden, large increases in salinity were injurious, whereas optimal acclimatization of the cultures of *Escherichia coli* with which he worked resulted with an increase of approximately 1.5 percent salt. It was desirable, therefore, to determine whether the more salt tolerant strains of *Aerobacter aerogenes* might not react differently than the other coliform cultures when suddenly transferred to an environment having a significantly higher salinity.

To test the effect of sudden contact with large increase in sodium chloride acclimatized cultures, cultivated in fresh 6 percent salt-glucose broth every 4 days for 90 days at 30° C., were transferred by loop directly to glucose broth media containing 9.0, 10.0 and 11.0 percent salt, respectively. The inoculated tubes were incubated at 30° C. for 10 days and then observed for the usual manifestations of growth. The results of the experiment are shown in Table 4.

TABLE 3

The effect of size of inoculum on the ability of coliform bacteria to tolerate salt

NaCl percent	Ml. of inoculum	Test cultures: 3 strains *A. aerogenes* (enrichment) 12 cultures	3 strains *A. aerogenes* (direct plating) 12 cultures	1 strain *A. cloacae* (direct plating) 4 cultures	1 strain *E. intermedium* (direct plating) 4 cultures	1 strain *A. aerogenes* control 4 cultures	1 strain *E. coli* control 4 cultures
		Number showing growth					
7.0	0.04						0
	0.1						0
	0.5						1
	1.0						1
7.5	0.04						0
	0.1						0
	0.5						0
	1.0						0
8.0	0.04		0		0		
	0.1		0		0		
	0.5		3		1		
	1.0		2		3		
8.5	0.04		0		0	0	
	0.1		0		0	0	
	0.5		0		0	2	
	1.0		1		0	3	
9.0	0.04			0		0	
	0.1			0		0	
	0.5			3		0	
	1.0			4		1	
9.5	0.04			0			
	0.1			0			
	0.5			0			
	1.0			0			
10.0	0.04	0					
	0.1	6					
	0.5	8					
	1.0	12					
10.5	0.04	0					
	0.1	0					
	0.5	1					
	1.0	4					

Sudden large increase in salinity did react detrimentally to the cultures obtained by direct plating as had been observed by Doudoroff *(4)* with cultures of *Escherichia coli*. However, such increases in salt did not prevent growth of the majority of the enrichment cultures of *Aerobacter aerogenes*. This experiment demonstrates once again that the enrichment strains of *Aerobacter aerogenes* are considerably more tolerant to salt than the other coliform bacteria studied.

D. The Transmissibility of Salt Tolerance

There is no agreement in the literature as to whether the salt tolerance of coliform bacteria results from temporary adaptation or mutation. Hof *(9)* claimed that the ability of *Escherichia coli* to grow in the presence of salt was not acquired through adaptation. However, both Doudoroff *(4)* and Severens and Tanner *(19)* have presented evidence to show that such an ability is acquired through adaptation. Doudoroff also found that acclimatized cultures of *Escherichia coli* soon lost their ability to tolerate large amounts of salt when they were returned to a salt-free environment, thus indicating that salt tolerance is an acquired yet reversible character. On the other hand, Severns and Tanner reported permancy of the salt tolerance acquired by their cultures of *Salmonella* and concluded that such permanency resulted from mutation.

TABLE 4

The effect of sudden large increase in salinity on growth of coliform bacteria

Bacteria [c]	Number of cultures tested	NaCl in medium, percent: 9.0	10.0	11.0
		Percent increase over inoculum [d]: 3.0	4.0	5.0
		Number showing growth [e]		
Aerobacter aerogenes (enrichment)	22	22	20	20
Aerobacter aerogenes (direct plating)	27	0	0	0
Aerobacter cloacae (direct plating)	3	0	0	0
Escherichia intermedium (direct plating)	3	0	0	0

[c] Acclimatized to 6 percent salt during 90 days at 30° C.
[d] The inoculum was approximately 0.04 ml. of culture.
[e] Incubated at 30° C. for 10 days.

It was demonstrated in the foregoing experiments that the cultures had a certain inherent ability to tolerate sodium chloride and that greater tolerance could be acquired through training. It therefore was desirable to determine whether the transmissibility of salt tolerance was temporary or permanent, i.e., reversible or irreversible.

Acclimatized and unacclimatized cultures of the same isolates were used for this experiment. The "trained" cultures had been growing in the presence of the highest concentrations of salt they could tolerate. Duplicate "untrained" cultures had been maintained in a salt-free medium. Both sets of cultures were streaked on Levine's E. M. B. agar. The agar for the acclimatized cultures contained four percent salt to reduce the "shock" which might retard their growth if they were transferred directly to a salt-free medium; that for the unacclimatized cultures contained no added salt. Four well-isolated colonies were picked from each plate. Thus, four subcultures of each acclimatized and unacclimatized isolate were obtained. These were maintained in fresh water glucose broth at 30° C. and transferred to fresh salt-free medium every 24 hours for the duration of the experiment. After each daily exposure to the salt-free environment a loopful of each sub-culture was transferred to glucose broth containing the highest concentration of salt that allowed the adapted to grow but did not permit growth of the unadapted ones. This procedure was repeated until cultures lost their ability to tolerate the usual high concentrations of salt. The results of the experiment are shown in Table 5.

Under the conditions of this experiment the cultures all lost their ability to tolerate salt. The time necessary for complete reversal of the phenomenon varied from 1 to 8 days, depending upon the species and strain of bacterium tested. Thus, the highly salt tolerant enrichment cultures of *Aerobacter aerogenes* required 7 to 8 successive transfers in a salt-free environment whereas the other coliform bacteria lost their acquired tolerance in 2 days or less. In this case at least, there is no permanent transmission of salt tolerance; the toler-

TABLE 5

The effect of a salt-free environment on transmissibility in salt tolerant cultures

Test cultures	Number of sub-cultures	Days in salt-free medium	NaCl in medium, percent											
			7.0		8.0		8.5		9.5		10.0		10.5		11.0	
			A	U	A	U	A	U	A	U	A	U	A	U	A	U
			Number of subcultures showing growth (30° C.)													
A. aerogenes (enrichment) 3 isolates	12	1									12	0	4	0	0	0
		2									4	0	0	0		
		3									4	0				
		4									4	0				
		5									4	0				
		6									4	0				
		7									4	0				
		8									0	0				
A. aerogenes (direct plating) 3 isolates	12	1			3	0										
		2			0	0										
A. cloacae (direct plating) 1 isolate	4	1							0	0						
E. intermedium (direct plating) 1 isolate	4	1					0	0								
A. aerogenes control 1 isolate	4	1			0	0										
E. coli control 1 isolate	4	1	0	0												

[1] A and U show tests made with cultures which at the start were acclimatized and unacclimatized, respectively. Blank spaces indicate no test was made.

ance acquired through gradual training is readily lost on return of the bacteria to a salt-free environment.

E. Morphological Changes Induced by a Saline Environment

It has been emphasized by Henneberg and Kniefall *(8)* and Doudoroff *(4)* that a saline environment causes a drastic change in the morphology of either *Escherichia coli* or *Aerobacter aerogenes;* the common manifestations of this effect being the marked tendency of the cells of either species to be elongated, to grow in pairs and chains and to form a clumped, mucoid sediment in the depths of the culture.

Similar morphological changes were observed with the coliform bacteria described herein. All of the cultures formed a mucoid sediment. However, in the case of the "enrichment" cultures of *Aerobacter aerogenes* a similar sediment was not observed except after long incubation unless the salt concentration was above 8 percent. At this level of salt the sediment was observed within 4 days.

The cells of all cultures, especially those belonging to the *Aerobacter* group were long and filamentous when grown in saline media. When the cultures which exhibited marked filamentation were transferred to fresh water glucose broth the filaments were replaced by chains of cells. After more cultivation in saltless media the bacteria appeared in pairs or elongated single cells. Eight days of exposure to a salt-free environment were required to return the elongated cells of the salt tolerant "enrichment" strains of *Aerobacter aerogenes* to their short, rod-shaped form.

Henneberg and Kniefall *(8)* also found other quite bizarre changes in the morphology of *Escherichia coli* and *Aerobacter aerogenes*. The authors were unable to observe any forms similar to those described and illustrated by Henneberg and Kniefall despite numerous attempts to cause development of such forms in the cultures studied.

III. Discussion

It appears from this study that the usual significance attached to the *Escherichia coli* group of bacteria as indicators of human or animal contamination may not be warranted in the case of salted foods which contain 7 to 10 percent salt. No *Escherichia coli* cultures were isolated from the cucumber or olive brines although every effort was made to isolate such bacteria and all samples were known to be subject to contamination. Other investigators also have failed to isolate cultures of *Escherichia coli* from samples of cucumbers or olives. Probably one of the most significant reasons for this failure is a marked difference in the ability of *Escherichia coli* and members of the genus *Aerobacter* to tolerate salt. It was shown that representatives of the genus *Aerobacter* were much more salt tolerant as a group than those few representatives of the genus *Escherichia* which were studied.

The proven existence of an especially salt tolerant type of *Aerobacter aerogenes* probably explains why (although it is commonly accepted in the industry that the presence of 10 percent salt in the brine will prevent "floater" spoilage of cucumbers and olives) some cases of such deterioration had been observed in the presence of more than 10 percent salt.

The origin of these highly salt tolerant cultures of *Aerobacter aerogenes* is somewhat obscured. It is evident that they are not widely distributed in nature for only 52 cultures were obtained from 300 different samples. Their distribution also is restricted for they were obtained only from 52 out of 125 samples of olive brines

although enrichments were attempted from 169 samples of cucumber brines and 6 samples of marine mud as well. Furthermore, even when these highly salt tolerant strains were present, they were sometimes present in very small numbers for, in about half of the samples, it was necessary to use 5 ml. of sample to obtain enrichment cultures of these bacteria.

One might, perhaps, attempt to explain this peculiar ecological situation by assuming that it is a manifestation of mutation which has occurred in olive brines but not in other saline environments. It is probable, however, that the highly salt tolerant cultures of *Aerobacter aerogenes* did not originate in so simple a fashion. It has been shown in the previous experiments that these cultures may be made resistant or sensitive to unusually high concentrations of sodium chloride at will. It is unlikely therefore that mutation, if responsible for origination of these salt tolerant forms, is responsible for any more than the inherent differences in salt tolerance noted for these cultures of *Aerobacter aerogenes* as compared with the more common types of coliform bacteria.

Nevertheless the highly salt tolerant strains are different. They possess an inherent tolerance to sodium chloride which is much greater than that of the other coliform bacteria either in an acclimatized or an unacclimatized state. Furthermore, as already stressed, their colony characteristics on Levine's eosine methylene blue agar also set them apart from the other coliform types. It must be remembered, however, that Ingram *(11)* has shown that salt interferes with bacterial enzyme activity. Thus, it may be that the enzyme system of these very salt tolerant cultures is quite different from those of the more sensitive types. Or, perhaps, the cell structures of these bacteria permit much less permeation of sodium chloride. This group of 52 cultures is completely homogeneous and, to the authors' knowledge, differs from the typical forms of *Aerobacter aerogenes* only in these two respects. While these differences do not necessarily warrant creation of a new species of *Aerobacter* to which to assign these highly salt tolerant strains, it might be desirable to use them to create a new variety or form of *Aerobacter aerogenes*.

It is thought that an acid tolerant form of *Aerobacter aerogenes* exists [Vaughn and Stadtman *(26)*]. If further investigation reveals that a completely homogeneous acid tolerant group of *Aerobacter aerogenes* cultures can be obtained from nature, then it certainly would be desirable to consider creation of variety or form nomenclature to properly set apart the specific types of *Aerobacter aerogenes*.

IV. Summary

A comparison was made of the relative salt tolerance of a collection of 85 cultures of coliform bacteria, freshly isolated from fermenting cucumber and olive brines. Thirty-three of the isolates, including 27 strains of *Aerobacter aerogenes*, 3 strains of *Aerobacter cloacae* and 3 strains of *Escherichia intermedium* were obtained from the brines by direct plating in Levine's E. M. B. agar. The other 52 cultures were isolated on E. M. B. agar after enrichment of the brines in glucose broth which contained 10 percent salt. These enrichment cultures, all apparently representative of the same type, were recovered only from olive brines. They were assigned to the species *Aerobacter aerogenes* but differed from the common types of this species in their appearance on E. M. B. agar and from all other coliform bacteria tested because of their marked resistance to sodium chloride.

Although this collection of coliform bacteria all inherently (i.e., unacclimatized) could tolerate the effects of 6.5 percent salt, their ability to tolerate significantly higher concentrations of salt was acquired through stepwise acclimatization. The additional resistance gained through training was readily lost on return of the bacteria to a salt-free environment thus indicating there was no permanent transmission of acquired salt tolerance. Thus it is evident that the salt tolerance above that which is inherent to the individual strains of coliform bacteria is selectively acquired through adaptation. Furthermore, the phenomenon is completely reversible as cultures which are resistant or sensitive to sodium chloride may be prepared at will.

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Preservation of Foods With Antibiotics. I. The Complementary Action of Subtilin and Mild Heat[a]

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A new principle in food preservation is announced, based on: (a) destruction of non-spore-forming bacteria, yeasts, fungi and enzymes by mild heat treatment, and (b) destruction of spore-forming bacteria with subtilin and mild heat. Supporting experiments are reported.

The principal applications of antibiotics have been in the field of medicine; little has been reported of their possible use in food preservation. Our work, mostly with vegetables, indicates that foods can be preserved with only mild heat treatment (212° F. or lower, for a few minutes) in the presence of very small amounts of subtilin, an antibiotic elaborated by a certain strain of *B. subtilis (5)*. Although other antibiotics have been employed in this study, and some (aureomycin, chloromycetin, and lupulon) have shown definite promise, the work so far has largely been confined to subtilin.[c]

The process[d] developed for preserving food is based on two principles: (a) the destruction of non-spore-forming bacteria, yeasts, fungi, and natural enzymes by mild heat treatment and (b) the destruction of spore-forming bacteria with mild heat and subtilin or other antibiotics singly or in combination. That the first of these principles is effective is well recognized. The second is supported by experimental data, which will be published later, and by the fact that foods treated with subtilin and mild heat as indicated below have been preserved for several months and found to be sterile by cultural methods.

In general a brief heat treatment of vegetables is required to inactivate enzymes which would otherwise cause deterioration during subsequent storage. Such treatment also is sufficient to destroy yeasts and fungi and all non-spore-forming bacteria, some of which are resistant to subtilin. On the other hand those organisms which are resistant to heat, such as clostridia and thermophiles, appear from our work to be extremely sensitive to subtilin, particularly with mild heat.[e] In the presence of the antibiotic, therefore, it is unnecessary to

[a] Editor's Note: The extraordinary significance of the brief exposition on a new principle of food preservation, contained in the following paper, will be apparent to those who have followed the development of food preservation methods. The authors have clearly indicated that the nature of possible physiological effects of subtilin and other antibiotics, if used in food, has not been determined—also that additional information must be obtained on the effects of heat on the antibiotic substances themselves before safe use can be made of the disclosed principle. This article, however, discloses some facts which are of signal scientific and technical interest, and possibly even of momentous commercial significance.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[c] The subtilin used was produced *(3)* and purified *(2)* at this laboratory.

[d] A public service patent covering this process is pending.

[e] *B. stearothermophilus* is completely inhibited in nutrient dextrose broth by 0.004 p.p.m. of subtilin. This suggests the possibility that flat sour spoilage in the canning industry might be eliminated by the addition of minute amounts of subtilin to the brine. *Cl. botulinum* (62A) spores heated for 5 min. (212° F.) in a brain-heart infusion containing 0.5 p.p.m. subtilin failed to grow within 7 months. The homologous strain of *B. subtilis* was completely inhibited in nutrient dextrose broth without heat treatment by 1 p.p.m. anaerobically and by 5 p.p.m. aerobically.

resort to the long cooking periods used in the canning industry.

The chief concern of this preliminary report is microbial spoilage. Further microbial studies and quality investigations of food processed by this new method will be discussed in later papers. In this investigation peas, asparagus, corn, green beans, peeled potatoes, tomato juice, and milk have been preserved from microbial spoilage. Experiments with peas, asparagus, and corn will be described here as illustrating the process and its effectiveness in food preservation.

Peas shelled by machine were washed, blanched 1 min., and 150 g. were weighed into each of 60 C-enameled No. 1 cans. In some cases the peas were inoculated with *B. stearothermophilus*. Two percent NaCl brine containing subtilin was added under vacuum to fill the cans. The subtilin concentrations were 0, 5, 10, or 20 p.p.m., based on total contents. The cans were sealed, heated in boiling water for 5 or 10 min. (after boiling was resumed), cooled, and incubated at 77° F. (25° C.). Those inoculated with the thermophilic bacteria were also incubated at 122° F. (50° C.) for at least one week.

All 14 controls (those heated but receiving no subtilin) promptly spoiled, as evidenced by swollen cans. Of 46 containing treated material, none has swelled in 64 days. Of 16 cans (2 of each treatment) that have been opened, all 4 controls were badly spoiled, and 2 cans receiving 5 p.p.m. of subtilin and 5 min. heat were slightly spoiled.[1] Cans receiving 5 p.p.m. and 10 min. heat, or 10 p.p.m. with 5 or 10 min. heat, or 20 p.p.m. with 5 or 10 min. heat, were all normal by our method of examination.

Asparagus was washed, spears were cut 3¾ inches long, blanched in steam 3 min., cooled, and 150 g. were packed into each of 40 plain No. 1 cans. These were then filled with 2% brine which contained subtilin to give a final concentration of 0, 5, 10, or 20 p.p.m. To each can, 110,000 spores of *B. stearothermophilus* were added. The cans were then heated to 200° F. in steam, sealed hot, heated in boiling water 10 or 20 min., and cooled in cold water. The pack was observed for spoilage after storage up to 106 days at 77° F. and an additional 7 to 14 days at 122° F.

All of the controls (without subtilin) spoiled; 3 of 5 receiving 5 p.p.m. of subtilin and 10 min. heat spoiled only slightly. There was no microbial spoilage in those receiving 5 p.p.m. subtilin and 20 min. heat, or 10 p.p.m. with 10 or 20 min. heat, or 20 p.p.m. with 10 or 20 min. heat.

Corn was steam blanched on the cob, machine cut, washed, and weighed into C-enameled No. 1 cans (180 g. each). Subtilin-brine solutions were added under vacuum to fill the cans, which were then closed. Only 0 and 20 p.p.m. subtilin were used in this experiment. The cans were heated in boiling water 5, 10, or 20 min. (after boiling was resumed), then cooled in cold water and incubated 30 or 45 days at 77° F. and 7 days at 122° F. Of 14 samples examined thus far, 9 treated ones have kept while 5 controls have spoiled.

The possible physiological effects of continued use of foods containing added antibiotics require careful consideration. The following facts suggest that subtilin would be harmless: (a) Subtilin is a polypeptide and is inactivated (presumably hydrolyzed) by proteolytic enzymes *(1, 4, 6)*. (b) Experiments in progress indicate that 100 p.p.m. in rat diets has not affected the growth or visibly affected the health in animals over a period of 175 days (personal communication from the Pharmacology Division of this Bureau). (c) In a single experiment with a rabbit, oral administration of a large dose of subtilin (1 g./kg.) caused no ill effects *(7)*. (d) Although *B. subtilis* is often found in foods, where it may well have produced appreciable quantities of subtilin, no case of food poisoning has ever been attributed to it. (e) The microflora of the intestinal tract are presumably not affected, because subtilin has no antibiotic effect against the Gram-negative bacteria which predominate there.

In this note we have announced a new principle in food preservation, outlined a tentative method for its application, and described experiments that illustrate the effectiveness of the process. The greatly reduced heat requirements as compared with present canning practice would shorten cooking times, eliminate the need for pressure heating equipment, and give promise of higher food quality.

[1] Spoilage was determined by appearance of the can and contents, odor, pH, and microscopical examination. Culture technics failed to detect spoilage in the frequent cases where the bacteria had died out after making growth, but it was unmistakably revealed by the measures indicated. "Slightly spoiled" samples showed slight turbidity of the brine, slightly lowered pH, and a relatively small number of bacteria by microscopic examination, but the vegetables appeared not to be significantly different from unspoiled samples. Presumably only very limited growth of the spoilage organisms had taken place.

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Influence of Storage Conditions on Ascorbic Acid Content and Quality of Canned Orange Juice[a]

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Changes in flavor and ascorbic acid content of canned orange juice during the period that palletized stacks are cooling to warehouse temperatures were found to be minor as compared to changes taking place during storage in a warehouse for seven or twelve months. The most satisfactory temperature for storage of canned orange juice from the viewpoint of cost as well as retention of quality and ascorbic acid appears to be between 40°F. and 50°F.

The consumer demand for orange juice is based primarily on its pleasing flavor and high vitamin C content. Therefore, in the development of procedures for the commercial canning of orange juice, much attention has been directed toward retention of the delicate flavor and the ascorbic acid of fresh, raw orange juice. Published data *(1, 5, 7)* demonstrate that the ascorbic acid contents of canned orange juice at the time of production is practically equivalent to that of the fresh, raw orange juice from which prepared. Changes in flavor and other factors influencing quality are only slight during the actual canning procedure.

It is generally recognized, however, that in many instances the quality of canned orange juice as it reaches the table may be somewhat deteriorated. Data obtained from several studies *(2, 3, 7, 8, 10, 11)* make it clear that temperatures under which this product is held from canning to consumption are major factors influencing flavor and ascorbic acid content of the juice when consumed. As pointed out by Riester et al. *(8)*, maintenance of a minimum warehouse temperature of 70° F. (21° C.) merits serious consideration by the citrus canning industry. At 70° F. (21° C.), there is some flavor change and approximately 85 to 90 percent of the ascorbic acid of the freshly canned product is retained during one year *(4, 8)*. At higher temperatures, deterioration of quality and ascorbic acid progresses more rapidly. At lower temperatures, 30 to 40° F. (—1 to 4° C.), quality and ascorbic acid of canned orange juice are little affected during one to two years storage *(8, 10)*.

Under usual conditions of production, canned orange juice is water-cooled to approximately 100° F. (38° C.) shortly after closure, then cased and stacked on pallets. A period of two to three weeks is required for the temperature of the product, in palletized stacks, to cool to the prevailing temperature of the air in the warehouse *(9)*. After the initial cooling period, the temperature of the product is dependent upon that of the surrounding air. As indicated by Riester et al. *(9)* and Monroe et al. *(6)*, temperatures of warehouses in citrus-producing areas may exceed 70° F. (21° C.) a good portion of the year.

Holding canned orange juice at 30 to 40° F. (—1 to 4° C.) would improve the flavor and ascorbic acid content of the product delivered to the consumer. However, under certain circumstances, maintenance of food in refrigerated storage may be expensive, becoming progressively more so as the storage temperature is lowered. Therefore, it is important to know the maximum temperature at which canned orange juice can be stored without objectionable change in flavor and with high retentions of ascorbic acid. It is also of interest to know whether water cooling to a lower temperature before casing or "super-cooling" would be beneficial.

The studies to be described were conducted to follow the changes in flavor and ascorbic acid of canned orange juice cooled to various temperatures and held under the following conditions:

1. During the period that the product in cases on pallets is cooling.
2. Storage for one year in a warehouse in a citrus-growing area.
3. Storage for one year at temperatures of 0, 30, 40, 50, 60 and 70°F. (—18, —1, 4, 10, 16 and 21° C.).

Experimental Procedure

Production of Orange Juice. Canned orange juice in No. 2 (307 x 409) plain tin cans, produced in Florida in March, 1947 from Pineapple Oranges and Valencia Oranges, was obtained for these tests. The juice was produced by methods which conform with good commercial practices of using equipment that is devoid of copper-bearing materials, and deaeration and flash sterilization were employed. Immediately after filling and holding for approximately 30 seconds to sterilize the cans, the product was passed through a spinner-type water cooler.

Storage During Cooling Period. The spinner cooler was adjusted to deliver cans to the casing machine at the desired temperature and 35 unsealed cases were placed on each pallet as shown in Figure 1. The pallets were

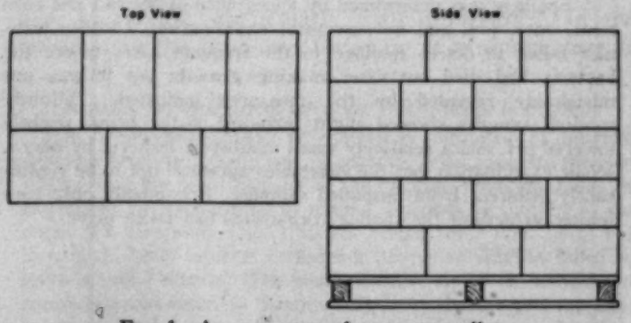

FIG. 1. Arrangement of cases on pallet.

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 13, 1949.
[b] Research Representative, Tampa, Florida.
[c] Deceased. Formerly Research Representative, Los Angeles, Calif.

placed in tiers, three pallets high, with approximately one to six inches between each tier. This method of stacking exposed at least one side of each case to a free air space. Two tiers were prepared from cans cased at 85-98° F. (29-37° C.); and two tiers from cans cased at 112-118° F. (44-48° C.). In addition, one pallet was prepared of cases containing cans of water cooled to 95° F. (35° C.) in the spinner cooler, then cooled in air during a period of four hours to approximately 70° F. (21° C.) prior to casing. Arrangement of the experimental pack in the warehouse is illustrated in Figure 2.

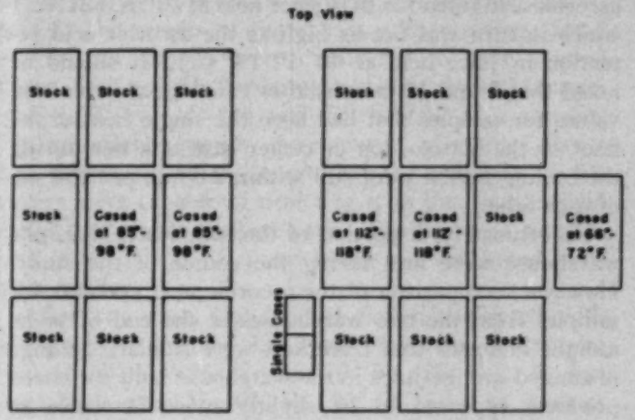

FIG. 2. Block of canned juice used in stack cooling tests.

During the preparation of the stacks, consecutive cases were taken from the line. A thermocouple was attached to one of the cans in a central position in the bottom layer of cans in each case. These cases were placed in center positions of alternate layers of cases in the three pallet tiers as a means of following temperature changes in various portions of the stack. Temperature readings were taken from seven to two times daily for a period of 16 days.

For each casing temperature, a case of control samples was cooled to 40° F. (4° C.) and 70° F. (21° C.) at the time of packing. An additional single case of orange juice (fitted with a thermocouple attached to one of the cans in the bottom layer) was placed on the floor beside the stacks.

Storage for Seven and Twelve Months. At the end of 16 day's storage, the stacks were taken down. Samples from cases which cooled at representative rates were selected for flavor evaluation and ascorbic acid determination. Other cans from these same cases were used to study the influence of storage under usual commercial conditions. Cans from several cases were placed in storage in each of two warehouses, one of which was designed for the storage of citrus products and the other for general storage. At the end of seven and twelve months storage in warehouses in a citrus growing area, samples were again examined along with the control samples held at 40° F. (4° C.) or 70° F. (21° C.) during the storage period.

Refrigerated Storage. For this study, 312 consecutive cans were removed from the production line following closing and cooled to 50° F. (10° C.) in ice water. After cooling, all samples to be held at 40° F. (4° C.) or lower were frozen at 0° F. (—18° C.) and shipped to the laboratory under dry ice refrigeration. Samples to be stored at higher temperatures were forwarded to the laboratory via express. On arrival, samples were placed in storage at 0, 30, 40, 50, 60 and 70° F. (—18, —1, 4, 10, 16 and 21° C.).

Examination Procedures. All ascorbic acid determinations were made by the 2,6-dichlorophenol-indophenol (dye) titration procedure. One milliliter of orange juice was added to 20 milliliters of three percent metaphosphoric acid and titrated. The dye solution was standardized against l-ascorbic acid. Flavor of the samples was judged by individuals experienced in tasting orange juice. In preparing a sample, the contents of six cans were mixed and aliquots for flavor estimation and for ascorbic acid analyses were taken from the composite sample.

Results

Initial Cooling Period. Results of temperature measurements made during 16 days after the stacks were built are summarized in Figure 3. Temperature

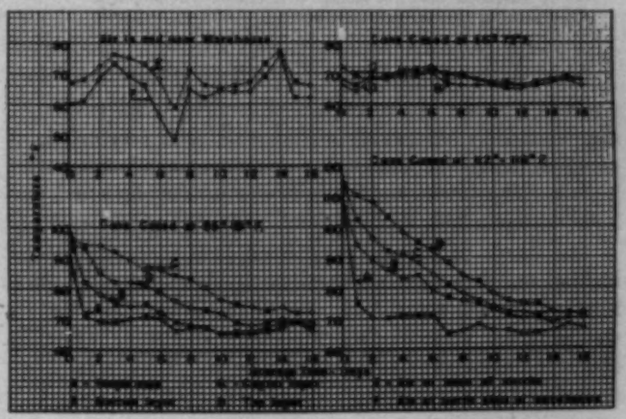

FIG. 3. Temperatures During Cooling of Stacks.

readings for the air in and near the warehouse fluctuated within rather wide limits during the day. However, temperatures inside the cases changed slowly. Therefore, only the average of the temperature readings taken throughout the day are shown. The patterns of these temperature studies made during a relatively cool period are similar to those observed by Riester et al. *(9)* during warmer weather.

The location of a case had a definite influence on the cooling rate. Within 48 hours of casing, the temperature in single cases placed on the floor had reached the air temperature. During the early stages of cooling, temperatures in cases within a tier differed by as much as 18° F. (10° C.). The bottom layers of a pallet or tier cooled more rapidly than the center or top layers. At the end of 16 days, all cases in a tier were within 6° F. (3° C.) of each other and independent of the temperature at which the cans had originally been cased.

The influence on ascorbic acid content of storage in the stacks during the initial 16 day cooling period, followed by storage in typical warehouses in Florida for seven or twelve months as compared to 40° F. (4° C.) or 70° F. (21° C.) are shown in Table 1 and Figure 4.

TABLE 1

Ascorbic Acid Contents of Canned Orange Juice Stored Under Warehousing Conditions in a Citrus-Producing Area

Storage Time Days	Storage During 16 Day Cooling Time*					
	40° F.	70° F.	Single Case	Bottom of Tier	Center of Tier	Top of Tier
Juice initially containing 50.4 mg. ascorbic acid per 100 ml. stacked at 66°-72° F.						
17 (1)	51.1	50.5	....	50.0	49.6	49.9
220 (1)	....	....	....	43.3	43.4	43.2
220 (2)	49.3	46.5	....	42.2	42.4	42.5
387 (2)	48.2	43.8	....	37.0	36.9	36.8
Juice initially containing 47.7 mg. ascorbic acid per 100 ml. stacked at 85°-98° F.						
17 (1)	47.7	47.1	47.3	47.6	47.0	47.0
220 (1)	....	....	40.7	40.6	39.8	40.2
220 (2)	46.8	43.4	39.2	38.1	39.7	38.9
387 (2)	46.0	41.8	34.8	35.2	35.0	35.4
Juice initially containing 51.1 mg. ascorbic acid per 100 ml. stacked at 112°-118° F.						
17 (1)	51.0	51.0	50.1	50.0	49.3	49.0
220 (1)	....	....	....	41.8	....	....
220 (2)	49.5	46.2	41.8	40.9	41.3	41.0
387 (2)	49.0	44.3	38.0	37.8	36.8	36.1

* Samples at 40° F. and 70° F. stored at these temperatures for duration of test; after initial cooling period other samples were stored on one pallet in the warehouse.
(1) A warehouse built for storage of canned citrus products.
(2) Space for general purpose storage.

At the end of 17 days, juice stacked at 115° F. (46° C.) showed a minimum retention of ascorbic acid values of approximately 96 percent. Ascorbic acid retentions in samples cased at the lower temperatures were even higher. The position of a case within the stack did not have a measurable influence on ascorbic acid retention.

The flavor of orange juice from cans that had cooled in the stacks was compared with the flavor of juice held at 40° F. (4° C.) or 70° F. (21° C.) for the 16 day period. None of the four to six individuals tasting the samples were consistently able to differentiate between the flavor of samples stacked at 70° F .(21° C.) or 95° F. (35° C.) and samples held at 40° F. (4° C.) or 70° C. (21° C.) for this period. In the lot of juice cased and stacked at 115° F. (46° C.), two of the individuals rather consistently detected a slight change in flavor as compared to samples held at 40° F. (4° C.). Even in this series of samples, no difference in the flavor of juice held in different parts of the pallet during cooling was found.

Prolonged Warehouse Storage. In Figure 4 and Table 1 observed changes in ascorbic acid contents of canned orange juice during storage in warehouses are summarized. Juice held in the warehouse had a lower ascorbic acid retention than juice held at 70° F. (21° C.) which in turn was not as high as the ascorbic acid retention in juice held at 40° F. (4° C.). It should be noted that 7 and 12 months after canning, ascorbic acid values for samples that had been the single case on the floor or the bottom, top or center case of a tier during the cooling period were still within 2.0 mg. per 100 ml. of each other.

Unfortunately, a portion of the samples held in one warehouse were lost during the course of the study. However, comparison of the ascorbic acid contents for samples from the two warehouses at the end of seven months indicates that retentions were similar. Storage of canned orange juice in the warehouse built for citrus products appeared to be slightly more favorable to ascorbic acid retention than in the warehouse used for general storage.

Refrigerated Storage. The samples used in this portion of the study were examined in two laboratories. Ascorbic acid values found in the two laboratories for the canned orange juice were in excellent agreement but for the sake of brevity, only the data from one laboratory need be presented (Figure 5 and Table 2). The maximum change in ascorbic acid observed during

TABLE 2

Ascorbic Acid Content of Canned Orange Juice Stored at Controlled Temperatures

Time (Days)	Ascorbic Acid Mg. per 100 Ml.				
	Initial	103	214	283	368
Temperature 0° F.	40.5	39.8	39.9	40.9	40.9
Temperature 30° F.	40.5	39.5	39.7	40.5	40.5
Temperature 40° F.	40.5	39.3	39.7	40.5	40.0
Temperature 50° F.	40.5	39.6	38.3	38.7	38.9
Temperature 60° F.	40.5	39.3	37.2	37.7	37.9
Temperature 70° F.	40.5	38.9	36.1	36.8	35.7

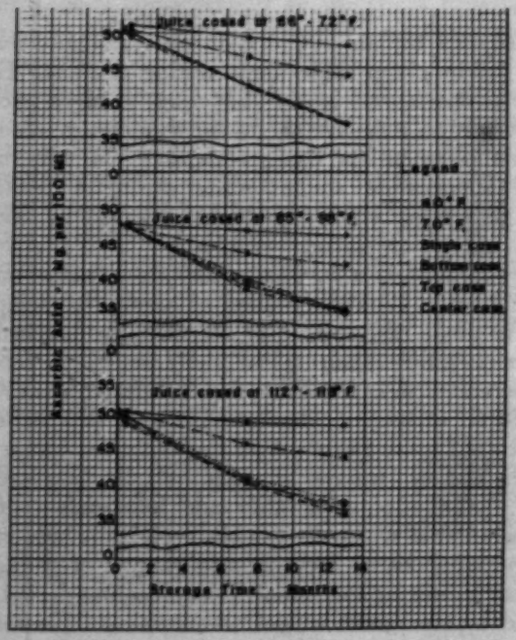

FIG. 4. Influence of Warehouse Storage on Ascorbic Acid in Canned Orange Juice.

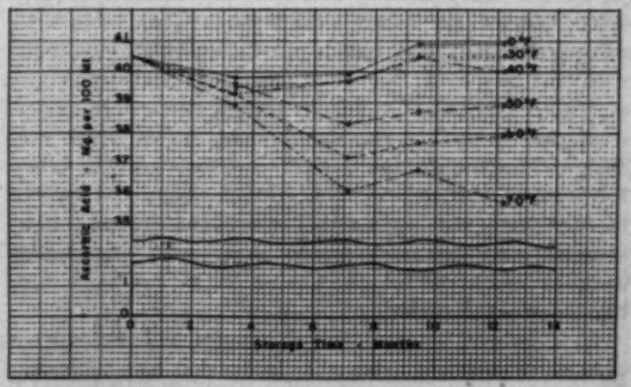

FIG. 5. Influence of Low Temperature Storage on Ascorbic Acid in Canned Orange Juice.

one year storage at 70° F. (21° C.) was 4.8 mg. per 100 ml. corresponding to about 89 percent retention. At 60° F. (16° C.) and 50° F. (10° C.), the ascorbic acid retentions were 94 and 96 percent respectively. Hence it appears that storage of orange juice at temperatures lower than 50° F. (10° C.) probably would not improve the ascorbic acid retention to an extent great enough to warrant the additional cost involved.

Samples examined at the time of packing were found to have an excellent flavor with a Brix reading of 14.2°, total acidity of 0.99 percent as citric acid and a pH of 3.48. The absence of objective methods for judging the flavor of foods makes it difficult to describe quantitatively the results of these tests. After storage for 3 months, all samples were considered to have a good flavor, with a slight flavor suggestive of storage changes in the 60° F. (16° C.) and 70° F. (21° C.) samples. By the seventh month, development of storage flavor had progressed to the point that the majority of the tasters were capable of detecting it in the samples held at the two higher temperatures. The flavor of samples held at 50° F. (10° C.) and lower was still found to be quite similar.

After one year, the type of flavor associated with storage was detected by most observers in samples held at 60° F. (16° C.) or 70° F. (21° C.). A few individuals rated the 60° F. (16° C.) juice as good as that stored at the lower temperatures. Samples held at 50° F. (10° C.) or lower were rated good by most tasters. In Table 3, the results of the final flavor

TABLE 3

Numerical Rank for Canned Orange Juice After Storage For Twelve Months

Storage Temperature	Individual Taster					
	1	2	3	4	5	Average
0° F.	1	1	1	1	1	1.0
30° F.	2	1	1	1	2	1.4
40° F.	4	3	1	1	3	2.4
50° F.	3	4	5	4	4	4.0
60° F.	5	5	1	4	5	4.0
70° F.	6	6	6	4	6	5.6

examination at one of the laboratories, in which the tasters were asked to range the samples in the order of preference with No. 1 for the preferred sample, are shown. These data indicate only slight differences in flavor for the three samples held at 40° F. (4° C.) or lower. It should be noted that certain of the individuals were capable of placing these samples in a sequence which closely corresponded with storage temperature.

Summary and Conclusions

The temperature of cans in palletized stacks of canned orange juice was found to be similar to the temperature of the air in the warehouse 16 days after packing. Ascorbic acid and flavor of the product 17 days after packing were not materially influenced by casing temperature employed or position of the case in the stock. During subsequent storage for 7 and 12 months in a warehouse in a citrus-producing area, ascorbic acid retentions were 80 to 86 percent and 71 to 75 percent respectively, and changes of flavor in the product associated with unfavorable storage conditions developed to a definite degree. Changes in canned orange juice during the period in which the cans were cooling in the palletized stacks were minor when compared to changes taking place during 7 to 12 months under the warehousing conditions studied.

Storage of canned orange juice at refrigerated temperatures was found distinctly favorable to retention of flavor and ascorbic acid. Lowering the temperature below 40° F. (4° C.) resulted in only slightly greater retention of freshness in the product at the end of storage for 12 months. The most satisfactory temperature for storage of canned orange juice from the viewpoint of cost as well as retention of quality and ascorbic acid appears to be between 40 and 50° F. (4° C. to 10° C.).

Acknowledgment

Appreciation is expressed to the Wm. P. McDonald Corporation, Auburndale, Florida for providing facilities for packing and storage of the canned orange juice used in these studies. The cooperation of the Fulton Market Cold Storage, Chicago, Illinois in making 30° F. (—1° C.) storage available is also appreciated.

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Effect of Steam Blanching on Quality of Frozen Peas

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Prolonged steam blanching at 212°F., up to three times that required for an adequate blanch, has little effect on the organoleptic quality of frozen peas. Peas have also been steam blanched at various lower temperatures (down to 190°F.) and for times from 38 to 210 seconds. Effects of the various treatments upon quality and storage stability of the frozen product have been determined by both physical and chemical as well as organoleptic methods.

Introduction

It was known as early as 1929 *(6)* that certain enzymes present in peas will cause off-flavors to develop after a few weeks of storage even at 0° F. or below. Heat is generally recognized as the most effective agent in inactivating these enzymes, but the best method of applying the necessary heat, the degree of heat to be employed, and length of exposure are more controversial points. Temperatures from 170° F. to 212° F. *(2, 7, 12)* have been recommended by various workers. Overblanching is said to produce changes in texture and flavor that may be as objectionable as underblanching *(7)*. It has been reported also that blanching at temperatures above 194° F. causes off-odors and flavors not usually associated with cooked peas *(7)*.

The problem of blanching peas involves many factors other than the inactivation of enzymes. At the time peas are being blanched, many other changes are occurring concurrently, such as leaching of solids, destruction of chlorophyll, flavor changes, splitting of the pea skins, and denaturation of proteins. After the peas are packed, each of these factors may affect the stability of the frozen product in storage.

In these experiments the effects of blanching time on leaching losses, chlorophyll destruction, ascorbic acid retention, splitting of pea skins, changes in composition of storage atmosphere, drained weights and volumes after cooking, and stability in storage at —10° F. were studied. Steam blanching was chosen in order to avoid additional variables that are found in water blanching, such as ion exchange and increase of solids in the blanching medium.

Raw Material

The peas used in these experiments were grown in the cool coastal area of San Mateo County, California (1947), where the climate is quite favorable for pea culture for several months of the year. The peas in pod were hand picked at proper maturity for quick-freezing, heavily iced in field crates as picked, and transported to the laboratory by truck. They were held in refrigerated storage (32° F.) and processed within 24 hours of picking. Analyses of shelled peas prior to processing are shown in Table 1. The following lots of peas were used:

Lot 1. Two thousand pounds (Laxton's Progress) picked May 14.

Lot 2. Two thousand pounds from same field as Lot 1, but picked May 16.

Lot 3. Seven hundred pounds (Alderman) picked August 18. Tenderometer readings: field run, 103; sieve size 4, 83; sieve size 6, 92.

Chemical and Organoleptic Methods

Duplicate representative samples of the raw and processed peas were taken for the following assays: Sugar by a modification of the method described by Hassid *(4)*; crude fiber by the official A. O. A. C. method; ascorbic acid by the Loeffler-Ponting method *(9)*; conversion of chlorophyll to pheophytin by a modification of the method used by Dutton, Bailey and Kohake *(3)*; catalase by a method published in the *Journal of the Association of Official Agricultural Chemists (1)*; and peroxidase by the method recommended by Masure and Campbell *(11)*. Adequacy of blanch was determined in all cases by testing for peroxidase activity. Total solids were determined by a two-stage vacuum drying process with duplicate one-pound samples. The number of peas in each sample was obtained by actual count so that all results could be calculated on a per-pea basis where desirable. The atmosphere in the storage containers was analyzed for carbon dioxide and oxygen (Orsat) in order to find leaky containers and determine changes in composition of the storage atmosphere. Samples showing evidence of defective seals were discarded.

The processed samples were cooked by carefully standardized procedures. The peas, while still frozen, were added to one-half their weight of boiling distilled water and cooked for five minutes after boiling was resumed. Since small variations in the pH of cooking water appreciably affect the color of cooked peas, the original pH was adjusted to 8.0 with sodium bicarbonate. A "standard sample" of frozen peas, for reference and comparison, was included, without identifying marks, at each panel session. These peas (Laxton's Progress) were processed as above, packed in nitrogen ($2 \pm 1\%$ oxygen) and stored at —30° F.

Color was scored subjectively on the whole cooked peas under special tungsten filament lamps filtered to approximate daylight (7400 K). Sweetness, characteristic flavor, and objectionable off-flavors were scored on a hot puree of the cooked peas, prepared by blending the peas with the cook liquor, plus the amount of water evaporated during cooking, until a smooth puree was obtained. The use of purees in taste panel work at this laboratory has proved satisfactory, since it eliminates the problem of differences between peas from the same sample and provides a more uniform sample for the panel.

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Small differences between two samples, such as those due to the effect of atmosphere, were evaluated by the "triangular" plan described by Helm and Trolle *(5)*. In these tests each panel member was presented with three samples with no identifying marks, two being duplicates and one an odd sample (AAB). At a later sitting the same samples were scored but were chosen so as to give the combination ABB. Each panel member was asked to select the duplicate samples. This method has been extremely useful in detecting small differences between two samples. The results are easily analyzed for statistical significance. The panel was composed of fifteen members selected by preliminary screening tests and from their past performance on previous pea-grading panels.

Processing

Peas in pods from Lots 1 and 2 were each divided into four representative sub-lots for processing consecutively so as to avoid undue delays between shelling and blanching. Lot 1 was processed May 15 and Lot 2 on May 17. Each of the sub-lots was machine-shelled, size-graded, and the sizes 3 to 6, inclusive, were retained for the experiments. Quality grading was not necessary, because overmature peas were rejected during picking. Duplicate representative samples from each sub-lot of raw material were taken for pea count, total solids, sugar, ascorbic acid, and crude fiber assays (Table 1).

TABLE 1

Analyses of Raw Peas

Analyses	Minimum Replicates	Raw Material Lot 1	Raw Material Lot 2
Total solids:			
Percent, wet basis,	36	18.9 ± 0.1	19.0 ± 0.1
mg./pea		87.9	92.7
Total sugar, as dextrose:			
Percent, wet basis,	18	7.12 ± 0.05	7.15 ± 0.08
mg./pea		33.2	34.8
Crude fiber, percent, M. F. B.	6	7.97 ± 0.17	8.06 ± 0.17
Ascorbic acid, mg./pea	9	0.161 ± 0.003	0.167 ± 0.004
Peas/100 g. wet basis	11	215 ± 3	205 ± 4

The peas were steam blanched on stainless-steel trays (1.5 lbs. per square foot of tray loading) in a belt-type blancher. Where blanching temperatures below 212° F. were required, air was injected into the line feeding steam to the blancher, with amount of air controlled automatically so as to maintain the temperature within a range of 2° F. Blanching times of 38, 55, 80, and 120 seconds at 212° F. were used for the four sub-lots from Lot 1, and 60, 120, 160, and 210 seconds at 190° F. were used for the four sub-lots from Lot 2. Determinations of adequacy of blanch *(11)* showed that 38 seconds at 212° F. was slightly longer than required for adequate blanching, while 120 seconds at 190° F. resulted in a barely adequate blanch.

After blanching, the peas were immediately placed under fog spray nozzles and held for one minute while the mist-laden air was drawn downward through the peas by a blower system capable of maintaining a free air velocity of 400 linear feet per minute. A minimum of water, consistent with rapid cooling (0.3 lb. per lb. of peas) was employed so as to minimize leaching losses during cooling. This treatment cooled the peas to 70° F. or below in the specified time.

The peas were frozen at —10° F. without removal from the trays, detrayed, and packed in 211 x 400 sanitary-type tinned cans (120 g. per can) and sealed on a semi-automatic vacuum double seamer. One-half of each sample of the eight sub-lots was sealed in air and the other half was gas packed by evacuating the sealing chamber prior to double seaming, and releasing the vacuum with oil-pumped nitrogen. This procedure reduced the oxygen content in these containers to 2 ± 1%. Replicate samples of each of the processed materials were assayed for total solids, sugar, crude fiber, catalase and peroxidase activity (Table 4), ascorbic acid, and conversion of chlorophyll to pheophytin. Pea counts (Table 4) were made on each of the replicate samples used for total solids determinations. All samples were stored at —10° F. until used.

The samples that were blanched at 212° F. were assayed for organoleptic quality initially, after 6 months, and after 12 months at —10° F. Characteristic flavor, objectionable off-flavors, sweetness, and subjective color were evaluated by panel methods as described above.

Effects of Blanching Time and Temperature on Frozen Peas

Chlorophyll. The conversion of chlorophyll to pheophytin, which involves loss of magnesium from the chlorophyll molecule and is evidenced by loss of the bright green color of fresh peas, proceeds progressively with increasing blanch time. As shown in Figure 1 the degradation of chlorophyll is more rapid at 212° F.

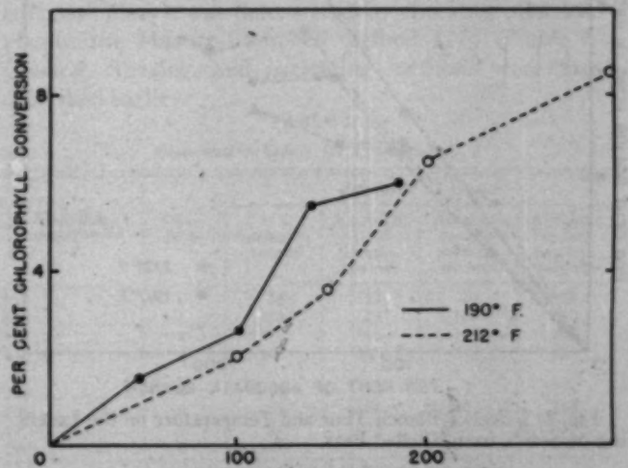

FIG. 1. Effect of Blanch Time and Temperature on Chlorophyll in Shelled Peas.

than at 190° F. A loss of 2.5% of chlorophyll occurred in peas blanched for 120 seconds at 190° F. (adequate blanch), while 8.5% was lost in 120 seconds at 212° F. (adequate + 200%). However, to attain a certain blanching treatment, such as adequate or adequate + 75%, at 212° F. and 190° F., the losses of chlorophyll were roughly the same at the two temperatures, since

the higher rate of conversion of chlorophyll to pheophytin at 212° F. is compensated by the longer blanching time required at 190° F. There is some evidence of a slightly higher loss of chlorophyll at 190° F., as has been pointed out by MacKinney and Weast *(10)*, but the difference under these conditions, if real, is very slight.

Leaching Losses. Leaching losses during processing are very difficult to determine accurately. Losses based on total-solids data alone are not valid, since loss or uptake of water in the processing introduces errors that cannot be corrected. This has been pointed out by Kertesz *(8)*. To avoid the introduction of such errors, losses of ascorbic acid, sugars, and total solids have been calculated on a per-pea basis (Figure 2). These are absolute values and are not influenced by loss or gain of water during processing. Losses of total solids are also calculated from crude-fiber data (Figure 2) on the assumption that none of the crude fiber is leached or lost during processing. If this assumption is true, any loss of soluble solids will result in a corresponding increase in percentage of crude fiber when expressed on a moisture-free basis (M. F. B.). The formula for computing leaching losses from crude-fiber data is as follows: percent loss $= 100\ (1 - \frac{x}{y})$ where x and y are, respectively, the crude fiber contents (M. F. B.) of the raw and processed material.

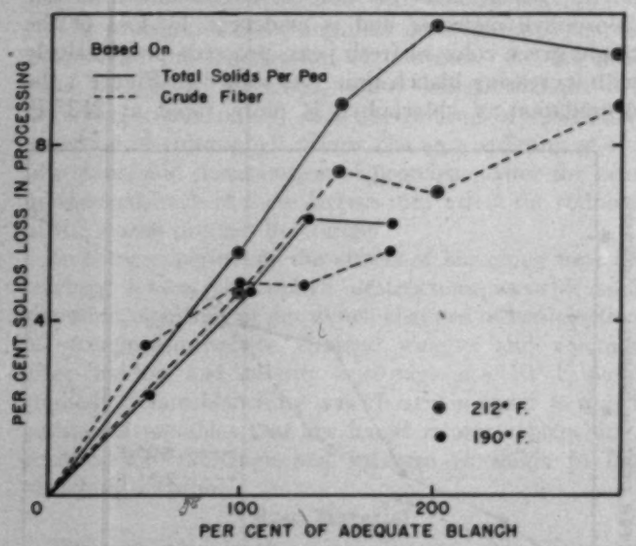

FIG. 2. Effect of Blanch Time and Temperature on the Leaching of Solids from Shelled Peas.

Losses of solids during processing (Figure 2), where a minimum adequate blanch was employed, were roughly the same, about 5% of the total solids, regardless of the blanching temperature (190° F. or 212° F.). Prolonged blanching, beyond the minimum required for an adequate blanch, resulted in progressive leaching losses which showed a tendency to level off at around 8 to 10% and 5 to 6% of the total solids, respectively, at 212° F. and 190° F. The higher leaching losses found at 212° F. are perhaps connected with the splitting of the pea skins under such conditions, as will be pointed out later. Leaching losses computed by the two methods, crude fiber and total solids, are in good agreement and are close to the minimum that may be expected in processing similar raw material.

Within the range covered, losses of ascorbic acid and sugars were not greatly affected by the blanching temperature (Figure 3). In obtaining an adequate blanch, approximately the same losses were found at 190° F. and 212° F. The loss of sugar tends to level off where

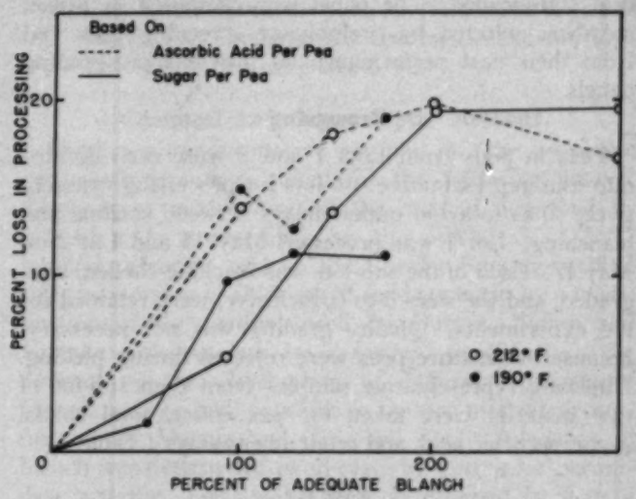

FIG. 3. Effect of Blanch Time and Temperature on Losses of Ascorbic Acid and Sugar in Shelled Peas.

blanching is prolonged at 190° F. beyond that required for an adequate blanch. Such is not the case with ascorbic acid, where rather large losses continued throughout the experiment. It should be pointed out that leaching is not necessarily the only factor involved in the loss of ascorbic acid. Under the conditions of this experiment, where air is being injected into the blancher to lower its temperature, oxidation of ascorbic acid might be more rapid at the lower temperature. At 212° F., losses of ascorbic acid and sugar tend to level off at around 20%.

Composition of Package Atmosphere. Composition of the atmosphere of the containers after storage for twelve months at —10° F. is shown in Table 2. Each value is the mean of 6 to 10 separate analyses. For corresponding samples, the amounts of carbon dioxide found in the containers were approximately the same whether the original package atmosphere was air or nitrogen. Where the samples were adequately blanched, the evolution of carbon dioxide and the oxygen uptake were small, ranging from 0.6 to 1.7% and 0.3 to 1.1% for the carbon dioxide and oxygen, respectively. Average initial oxygen contents of 2 and 21%, respectively, are assumed in the atmospheres of the nitrogen- and air-packed containers. The underblanched samples (60 seconds at 190° F.) evolved more carbon dioxide (4.4%) and showed a somewhat higher oxygen uptake than any of the other samples. As blanching times increased, somewhat lower percentages of carbon dioxide were found in the containers.

TABLE 2

Composition of Package Atmosphere After Twelve Months' Storage at —10° F.

Blanching Time, Seconds	Blanching Temperature	Composition of Package Atmosphere			
		Nitrogen Pack		Air Pack	
		Percent CO_2	Percent O_2	Percent CO_2	Percent O_2
38	212° F.	1.6 ± 0.2	1.4 ± 0.2	1.4 ± 0.2	20.2 ± 0.1
55	212° F.	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.2	20.3 ± 0.1
80	212° F.	1.0 ± 0.3	1.5 ± 0.1	1.1 ± 0.1	20.3 ± 0.2
120	212° F.	0.6 ± 0.1	1.5 ± 0.2	0.7 ± 0.1	20.5 ± 0.2
60[a]	190° F.	4.4 ± 0.2	0.8 ± 0.1	4.4 ± 0.2	18.8 ± 0.2
120	190° F.	1.7 ± 0.2	1.7 ± 0.2	1.9 ± 0.1	20.2 ± ....
160	190° F.	1.4 ± 0.5	1.7 ± 0.6	1.8 ± 0.1	20.1 ± 0.1
210	190° F.	1.2 ± 0.1	0.9 ± 0.1	1.6 ± 0.1	20.1 ± 0.1

[a] Underblanched sample.

Effect of Atmosphere on Organoleptic Quality. Samples of frozen peas with identical processing history and differing only in storage atmosphere (air and nitrogen) were compared by the "triangular" plan after 12 months' storage at —10° F. When the data for all panel members were considered, no statistically significant differences were found. Five members of the panel, however, consistently identified duplicate samples and favored samples stored in nitrogen, but they judged too few samples for statistical analysis of the data.

Effect of Blanching Time on Organoleptic Quality. Samples of frozen peas steam-blanched at 212° F. for 38, 55, 80, and 120 seconds were scored on a five-point scale for characteristic flavor, sweetness, and objectionable off-flavor immediately after freezing, and following 6 and 12 months of storage at —10° F.; color was scored after 6 and 12 months of storage. No statistically significant differences were found in any of the samples initially or after 6 months of storage at —10° F. After 12 months, barely significant statistical flavor differences ($P = .05$) were found between the samples blanched 55 and 120 seconds. However, when these two samples were compared by the "triangular" method, the same panel could not identify duplicates.

Color scores (Figure 4) on the samples immediately after freezing are not available. Samples with the shortest blanch time received the best color rating at both storage intervals.

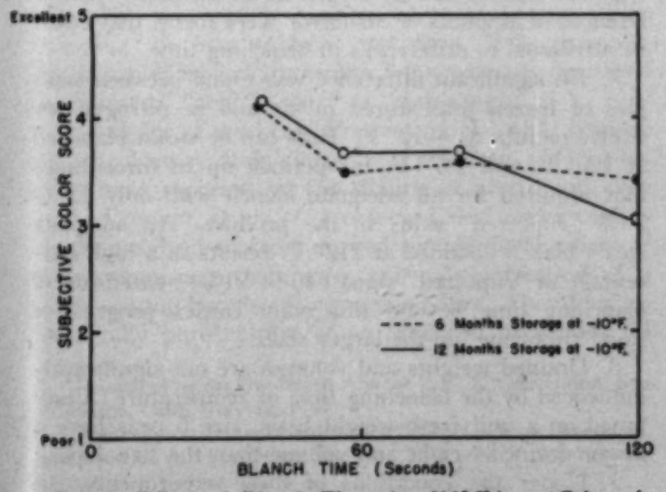

FIG. 4. Effect of Blanch Time (at 212° F.) on Color of Frozen Peas After Six and Twelve Months' Storage at —10° F.

No attempt was made to compare data obtained at different storage periods, since the changes observed in the samples during 12 months were small. However, these year-old peas, when compared by the "triangular" method with freshly frozen peas from the 1948 pack, were found to be significantly different and to have acquired a slight "hay-like" or "storage" flavor that enabled a high percentage of the panel to identify duplicate samples.

Changes during storage for 12 months at —10° F. were so small that all samples received scores which indicated that they were good to very good in flavor. It should be borne in mind that the minimum blanching time in this series was sufficient for an adequate blanch.

Effect of Blanching Time on Ascorbic Acid Retention

Losses of ascorbic acid mounting to 4, 0.3, 1.5, and 9% were found in the air-packed samples (blanched at 212° F. and arranged in order of increasing blanch time) after 12 months at —10° F. The losses were small in all cases and are perhaps within the limits of the combined errors from sampling and from the analytical method.

Effect of Blanching Time and Temperature on Number of "Ruptured" Skins and on the Drained Weight and Volume After Cooking. Peas in pod from Lot 3 were shelled, size graded, and sieve sizes 4 and 6 retained separately for the experiment. The raw material was processed and packed in sub-lots of 275 grams so that processed peas, after cooking, could be converted back to a fresh-weight basis. Duplicate sub-lots of the sieve sizes 4 and 6 were steam blanched as described above on 8 x 8 inch stainless steel trays at temperatures and times shown in Table 3. The time required for an adequate blanch was determined by checking pilot samples by the Masure-Campbell method *(11)* (Table 4). Cooling, freezing, and packaging methods were those described earlier.

TABLE 3

Blanching Schedule for Peas (Lot 3)

Blanching Temperature F.	Sieve Size	Adequacy of Blanch			
		Adequate, seconds	Adequate + 50 percent, seconds	Adequate + 100 percent, seconds	Adequate + 200 percent, seconds
212	4	38[a]	57	76	114
204	4	50	75	100	150
197	4	70	105	140	210
190	4	100	150	200	300
212	6	38	57	76	114
204	6	56	84	112	168
197	6	76	119	152	229
190	6	110	165	216	330

[a] Slightly more than adequate.

TABLE 4

Enzyme Content as a Function of Blanching Conditions

Analyses	Minimum Replicates	Blanching Time in Seconds at 212° F.				at 190° F.			
		38	55	80	120	60	120	160	210
Residual peroxidase, percent	2	2.0	0	0	0	14	0.5	0	0
Residual catalase, percent	2	0.33	0	0	0	18	0	0	0
Peas/100 g., wet basis	2	232	243	249	248	223	224	226	232

The number of "ruptured" and split skins in the various samples was determined by thawing the packaged peas in running water and making an actual count of the "ruptured" and split skins. According to the terminology used in this experiment, peas with "ruptured" skins had definite cracks but the skin and cotyledons had not separated. "Split" peas (with skins and cotyledons separated) constituted defects as defined by the U. S. Department of Agriculture standards for frozen foods *(13)*.

To determine drained weights and volumes, the various samples were cooked as described earlier, drained for one minute on a Büchner filter with vacuum, weighed without removal from filter, poured into graduated cylinders for measurement of volume.

The effect of processing on the "rupturing" of pea skins is shown in Figure 5. The differences can be attributed to differences in blanching treatment with a reasonable degree of certainty, since other steps were identical. Where blanching temperatures did not exceed 197° F., blanching time had no effect on the number of "ruptured" skins, within the range studied. The number of peas with "ruptured" skins, ranging from 15 to 20% with the lower values for the smaller size, is perhaps related to the type of machine used in shelling the peas. Blanching temperatures as high as 204° F.

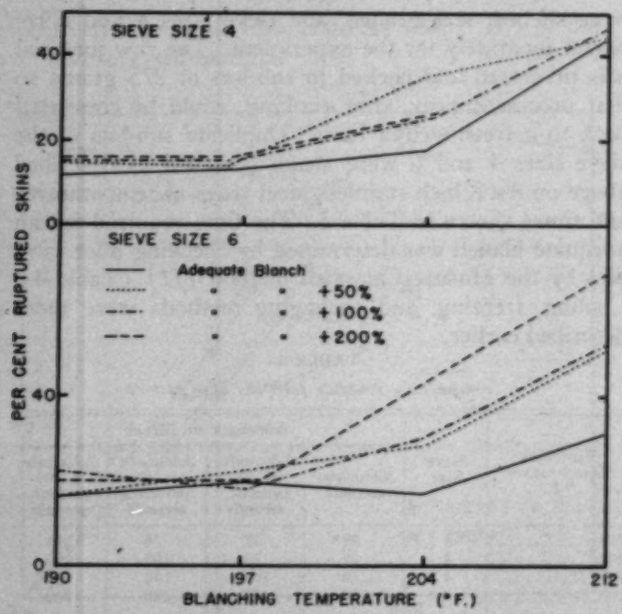

FIG. 5. Effect of Processing Conditions on Rupturing of Pea Skins. Frozen Peas After Thawing.

did not result in a substantial increase in "ruptured" skins, where the minimum time for an adequate blanch was employed. Heating at 204° F., in excess of this minimum time and within the range of the experiment, produced an increasing number of "ruptured" skins, amounting to about 40% for the longest blanching time. The use of 212° F. in blanching resulted in a high percentage of "ruptured" skins, 30 to 40%, with the minimum time employed. This was 38 seconds and was slightly in excess of that required for an adequate blanch. Longer blanching times had little further effect on the smaller size but caused progressive rupturing in the larger peas, reaching about 70% after 120 seconds. The smaller peas were apparently somewhat less susceptible to skin "rupturing" than the larger size.

The percentage of "split" and broken peas was quite small and less than 1% in all cases. The percentages were somewhat lower for the larger peas.

Blanching time and temperature had little effect on the drained weights and volumes after cooking. The drained weights and volumes of the various samples (for 100 g. peas, fresh-weight basis) averaged 77 g. and 110 ml., respectively, for size 4, and 82 g. and 122 ml., respectively, for the size 6 peas.

Conclusions

1. In obtaining an adequate steam blanching treatment for peas, based on peroxidase, approximately the same leaching losses (about 5%) can be expected with blanching temperature of 190° F. or 212° F .

2. Injection of air into the blancher to lower its temperature does not appear to cause undue losses of ascorbic acid in the blanched peas.

3. Losses of about 5% of the total solids during processing for quick-freezing may be expected under almost ideal conditions. Where peas are contacted with water after blanching, as in quality grading, washing, or fluming, much higher leaching losses are likely to be encountered.

4. Prolonged steam blanching (212° F.), up to three times that required for an adequate blanch, had little effect on the initial organoleptic quality of the frozen peas.

5. Samples with the shortest blanching treatment received the best color rating at both storage intervals. After 6 and 12 months of storage at —10° F., samples of peas receiving the minimum adequate blanch (at 212° F.) were given better color ratings than those with longer blanching treatments at the same temperature.

6. No significant changes in sweetness, characteristic flavor, or objectionable off-flavor were apparent after six months' storage at —10° F. After 12 months, very slight off-flavors had developed in all samples. No differences in amounts of off-flavor were found that could be attributed to differences in blanching time.

7. No significant difference was found between samples of frozen peas stored in air and in nitrogen for twelve months at —10° F. Peas can be steam blanched at 190° F. and 197° F. for periods up to three times that required for an adequate blanch with only 15 to 20% "ruptured" skins in the product. An adequate steam blanch obtained at 212° F. results in a high percentage of "ruptured" skins (40 to 50%); extension of blanching time beyond this point causes progressive skin "rupturing" in the larger sizes.

8. Drained weights and volumes are not significantly influenced by the blanching time or temperature. Computed on a unit fresh-weight basis, size 6 peas have a larger drained weight and volume than the size 4 peas.

9. Under the conditions of these experiments, the percentages of "splits" and broken peas were unimportant—less than one percent in all samples.

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Post Mortem Changes in Stored Meats

I. Microorganisms Associated with Development of Slime on Eviscerated Cut-up Poultry[a, b]

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Development of off-odor and slime on the surfaces of cut-up chicken is associated with growth and coalescence of colonies of several species of Pseudomonas. The initial contamination of processed birds and the temperature of storage greatly influence their keeping time. The total load of organisms reaches a value of approximately 10^8/sq. cm. by the time that off odor and slime develop.

Introduction

With the rapid increase in the sale of ready-to-cook poultry, particularly ice-packed cut-up birds, the development of "slime" in the butcher's show case and in the home refrigerator has become a problem of considerable importance. This defect appears as a glistening, slick and rather gummy white to creamy layer covering the lean surfaces and skin. It is generally accompanied by a characteristic odor variously described as "tainted," "acid," "sour" or "dish-raggy."

A number of workers [Prescott, et al. *(15)*; Haines, *(6, 7)*; Empey and Vickery *(1)*; Moran *(14)*; Fisk *(2)*] have reported on the sliming of stored unfrozen beef. Prescott, et al. *(15)* observed that under certain conditions, beef surfaces showed a rapid development of microorganisms which gave not only formation of a slimy coating but also disagreeable odors. They found a practically pure culture of an unnamed bacterium responsible for these changes. Haines *(6, 7)*, Empey and Vickery *(1)* and Moran *(14)* indicated that slime on meat is due to organisms of the *Achromobacter* and *Pseudomonas* types.

According to Moran *(14)* spoilage in stored, unfrozen beef is primarily a surface phenomenon. Specifically, Moran and Smith *(13)* showed that there was a negligible increase in the number of organisms in the deep flesh of beef stored for two weeks at 41° F. During the period of their test Lochhead and Landerkin *(9)* regarded the bacterial counts which they obtained from examination of the breast tissue of dressed chickens as being too low to indicate microbial decomposition.

Although sliming of cut-up chicken is a defect generally recognized throughout the industry and, apparently, is a condition analogous to the defect found in sliming of beef, no reference has been found relating to a study of this condition in eviscerated poultry. Mallmann *(11)* has described a slippery condition in dressed squab ducklings in which the incriminated microorganisms were spore-forming capsulated bacilli closely resembling *Bacillus mesentericus*. A characteristic odor caused by bacteria multiplying on the skin surface of dressed chickens stored at 30° F. and at 32° F. was detected by Lochhead and Landerkin *(9)*. Presumably birds in this study were New York dressed, although the method of preparation was not given. These workers did not describe the odor that developed other than to state that it was an initial sign of spoilage and that it did not become apparent until the bacterial count on the skin exceeded 2.5 million organisms per square centi-

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[b] Appreciation is expressed to the Pure Carbonic Company, a division of Air Reduction Co., Inc., N. Y., N. Y. for support, in part, of this research.

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meter. Six predominant types of bacteria found developing on the skin during storage were identified as representative of the genera *Micrococcus* (2), *Flavobacterium* and *Achromobacter* (3).

Commercial eviscerated poultry were found by Gunderson et al. *(4)* to have a heavy surface load of microorganisms. Coliform organisms were found to be especially prevalent. Later Gunderson, et al. *(5)* reported numerous *Escherichia* and *Aerobacter* isolates, and, of one hundred eighty-six other strains specifically studied, found representatives of the following genera: *Micrococcus* (5), *Alcaligenes* (38), *Achromobacter* (34), *Paracolobactrum* (13), *Flavobacterium* (9), *Proteus* (7), *Bacillus* (7), *Pseudomonas* (6), *Staphylococcus* (4), *Microbacterium* (4), *Eberthella* (3), *Sarcina* (2), *Diphtheroids* (2), *Gaffkya* (2), *Streptococcus* (1), *Corynebacterium (gallinarum)* (1), *Neisseria* (1), *Oidum* (1), *Torula* (1).

In view of the work cited above it seems logical to associate slime formation on chicken meat with the growth of microorganisms. This assumption, coupled with the information obtained from the opinions and observations already related, prompted the present workers to investigate the possibility of an interrelationship among numbers and kinds of organisms, formation of odor, and the development of slime on poultry meat. In addition, sanitary implications that might arise from poor methods of handling were considered.

Materials and Method

Poultry. Live fryers (2½-3½ lbs.) were obtained from the College Poultry Farm and killed by severing the jugular vein. An electric shock was applied to the head to prevent struggle. The birds were semi-scalded for 30 seconds in water at 130° F. (54.5° C.); after the feathers were removed, the birds were eviscerated and cut up into ten pieces as follows: legs (2), thighs (2), wings (2), back (2) and breast (2). In addition, cut-up fryers were purchased from several local wholesale and retail outlets. Some frozen cut-up birds were procured from commercial eviscerating plants; these were maintained in the frozen condition at —10.° F. (—23.3° C.) until ready for use. Others were purchased from local grocery stores. In all cases the frozen birds were defrosted for 24 hours at 50° F. (10° C.) immediately before studies were begun.

Storage methods. Generally legs, thighs and backs were used for storage studies since these pieces afforded sufficient lean or skin surfaces to allow for several samplings without an overlapping of the areas during the period of test. The same pieces from the right and left sides of one bird were compared at 50° F. (10° C.) and 40° F. (4.5° C.) or at 40° F. and 32° F. (0° C.) insofar as this was practicable. In all cases pieces from the same lot of birds were placed at each of the three temperatures.

Individual pieces were stored in sterile one-quart Mason type jars sealed with rubber stoppers. Ten ml. of water were added to the bottom of each jar to give a relative humidity approaching 100%.

Bacterial counts. Samplings were obtained by removing a thin section from the lean surfaces or by swabbing a definite area and counts were reported as the number of bacteria per square centimeter.

(1) *Cut sections.* A sterile cork borer having an area of 2 sq. cm. was used and, after cutting, the segment was excised with a sterile scalpel. The section of tissue was disintegrated by mixing with 100 ml. of water in a sterile Waring Blendor for a period of one minute. Serial dilutions of the mixtures were used in making pour plates which were incubated at 68° F. (20° C.) for four days.

(2) *Swab areas.* A sharp cork borer was used to cut holes having an area of 2 sq. cm. in filter paper strips. A strip so prepared was placed on the meat surface and the enclosed area carefully wiped with a moistened swab. The cotton portion of the swab was then aseptically transferred to a six-ounce prescription bottle containing 100 ml. of sterile water. A standardized manual shaking period was used. After shaking, serial dilutions of the mixture were used in making pour plates which were handled as indicated above.

Various media were employed for determining the microbial loads. Malt agar, Czapek-Dox agar and eosin methylene blue agar, respectively, were used for yeasts, molds and enteric organisms. Nutrient agar, chicken infusion agar and nutrient agar containing 0.4% gelatin were utilized for total and chromogenic counts.

Chicken infusion agar was prepared by taking 500 g. of ground lean chicken meat and 1000 ml. of water and infusing overnight in a refrigerator. The infusion was strained through cheesecloth and made to original volume by adding water. All fat was skimmed off and discarded. Following steaming for thirty minutes in an Arnold sterilizer, the infusion was filtered through cotton flannel and filter paper. To this liquid, 1% peptone, 0.5% yeast extract, 0.5% sodium chloride and 1.5% agar were added and the medium adjusted to pH 7.2. After the medium was placed in 100 ml. amounts in 6 oz. prescription bottles, it was sterilized at 250° F. (121° C.) for twenty minutes.

The Frazier *(3)* procedure was employed for determining gelatin liquefiers. Pour plates were made in nutrient agar containing 0.4 percent gelatin as the principal source of nitrogen. These were incubated at 68° F. (20° C.). After incubation the plates were flooded with acid-mercuric chloride solution. This reagent causes the formation of a white opaque precipitate except in those zones immediately surrounding gelatin liquefying colonies.

Organisms. The colonies were classified on the basis of chromogenesis. Also, individual colonies presenting different morphological or cultural properties were picked from plates prepared at the time that incipient spoilage or slime formation was in evidence and were placed on agar slants or in nutrient broth. After growth in subculture, Gram-stains and biochemical screening tests were performed. The organisms which were indistinguishable by macroscopic appearance, Gram reaction or motility were differentiated on the basis of their activity in gelatin, litmus milk, dextrose, maltose and fructose media. Finally, flagella stains were made and on occasion a large number of other biochemical

tests were made. Whenever possible, the different types of microorganisms were identified in accordance with descriptions given in Bergey's Manual of Determinative Bacteriology (6th ed.). Reactions were recorded after 1, 2, 4, 7, 14, 30, 45 and 60 days of storage at 20° C. In sugar fermentation tubes phenol red was added as an internal indicator. Motility was determined by microscopic examination of hanging drop preparations of young cultures (16-20 hrs.) from nutrient broth or by visual observation of diffuse growth spreading from the point of inoculation in SIM medium. Indol and H_2S determinations also were made from this last named medium.

Results

A characteristic sweetly rancid odor which might also be described as a "dirty dishrag" odor developed when the cut-up chickens were stored for a sufficient time at high humidities. Accompanying this off-odor minute, translucent, moist colonies appeared in large number on the cut surfaces and skin of the bird. At first these colonies gave a superficial appearance of being droplets of moisture; later, however, they became larger and white or creamy in color and often coalesced as a rather uniform sticky or slimy layer. In this final stage the meat had a pungent ammoniacal odor in addition to the "dirty dishrag" odor.

Figure 1 shows the growth curves obtaining at 32°, 40° and 50° F. Here the daily counts are plotted

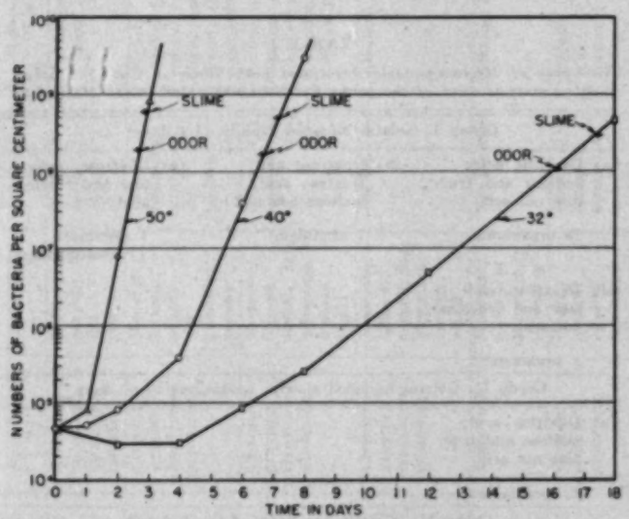

FIG. 1. Growth curves showing relationships among bacterial counts, off-odor and slime formation at 32°, 40° and 50° F.

against time on semi-logarithmic paper. The individual points represent averages obtained from twelve separate studies of commercial fresh and frozen cut-up birds. In every case a perceptible off-odor preceded production of slime. Also, regardless of the storage temperature, off-odor and slime did not appear until the numbers of organisms had reached certain levels.

Counts using cut sections of flesh and swab areas covering an equal amount of surface were obtained. The results are given in Figure 2. It may be seen (Figure 2) that the two techniques used for sampling portions of lean surface gave comparable results. The depth of sample was not important insofar as total

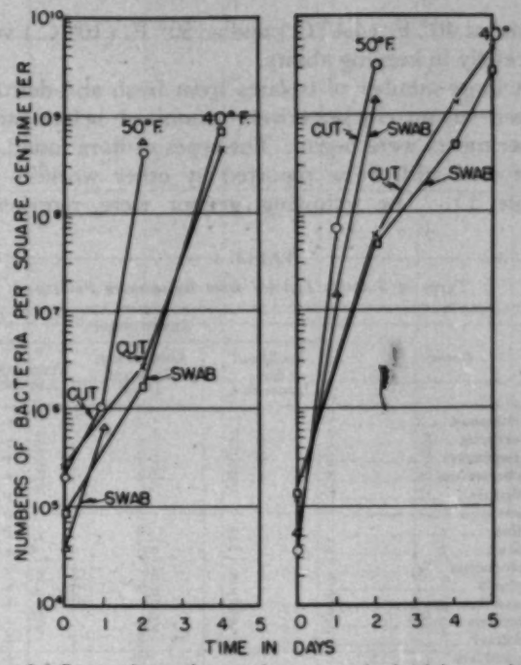

FIG. 2. Comparison of growth curves obtained by swab and cut-section sampling methods.

counts were concerned. This was contrary to expectations and in rather good agreement with the work of Lochhead and Landerkin *(9)*. However, cut samples taken late in the storage period might be expected to have higher loads due to penetration of the tissue by surface bacteria. In view of the good correlation shown between the two methods, all subsequent studies were made using the simpler swabbing technique.

The storage life of the individual pieces of chicken was found to depend upon their initial quality as is shown in Figure 3. High, moderate and low count cuts

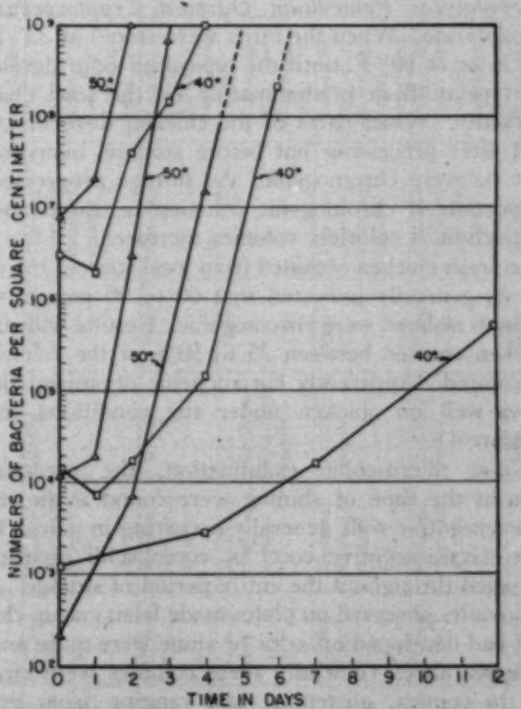

FIG. 3. Effect of a high, average or low initial bacterial load on keeping quality.

stored at 40° F. (4.4° C.) and at 50° F. (10° C.) varied markedly in keeping ability.

A large number of isolates from fresh and defrosted, frozen cut-up chickens were examined before storage experiments were begun. The types of flora found compare well with those reported by other workers (See Table 1). The following genera were represented:

TABLE 1

Types of Bacteria Isolated from Eviscerated Poultry

Genus	Investigators		
	Lochhead and Landerkin	Gunderson, Ross and Henn	Ayres, Ogilvy, and Stewart
Pseudomonas		+	+
Micrococcus	+	+	+
Achromobacter	+	+	+
Flavobacterium	+	+	+
Alcaligenes		+	+
Proteus		+	+
Bacillus		+	+
Sarcina		+	+
Streptococcus			+
Eberthella		+	+
Salmonella			+
Escherichia		+	+
Aerobacter		+	+
Streptomyces		+	+
Penicillium			+
Oospora		+	+
Cryptococcus			+
Rhodotorula			+
Paracolobactrum		+	+
Staphylococcus		+	+
Corynebacterium		+	
Actinomyces		+	
Hemophilus		+	
Torula		+	
Neisseria		+	
Diphtheroids		+	
Gaffkya		+	
Microbacterium		+	

Pseudomonas, Micrococcus, Achromobacter, Flavobacterium, Alcaligenes, Proteus, Bacillus, Sarcina, Streptococcus, Eberthella, Salmonella, Escherichia, Aerobacter, Streptomyces, Penicillium, Oospora, Cryptococcus and *Rhodotorula*. When the birds were stored at 32° F., at 40° F. or at 50° F. until the typical off-odor developed, the type of flora predominating on the fowl changed markedly. When parts of the chicken were first sampled after processing but before storage, many of the bacteria were chromogenic. As storage progressed the proportion of chromogenic colonies decreased and the proportion of colorless colonies increased.

In fresh chicken obtained from local sources the initial counts generally indicated that 60 to 90 percent of all colonies isolated were chromogenic. Results with frozen chicken showed between 25 to 50% of the colonies to be colored. Apparently chromogenic organisms do not grow well on chicken under the conditions studied (Figure 4).

Upon microscopic examination, the predominant flora at the time of sliming were found to be motile, Gram-negative rods generally occurring in pairs. However, Gram-negative cocci or coccobacilli occasionally persisted throughout the entire period of storage.

Colonies observed on plates made from cut-up chicken that had developed off-odor or slime were quite uniform in appearance. Generally these colonies were circular, flat to convex, glistening, and ranging from grayish through white to creamy or buff in color.

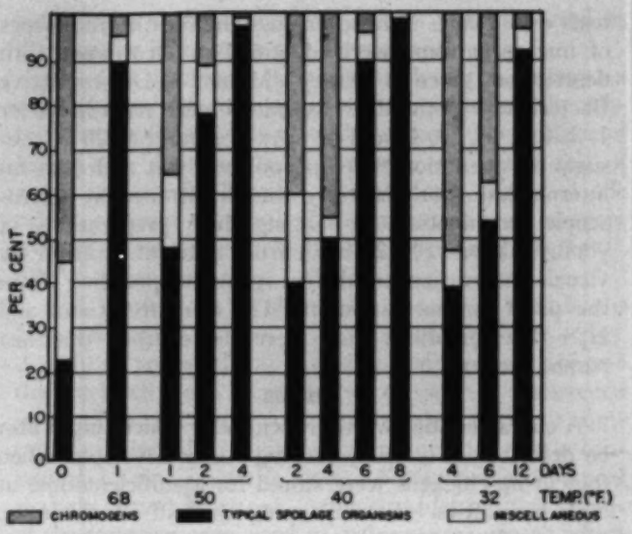

FIG. 4. Effect of storage time on proportions of chromogenic, spoilage and miscellaneous bacteria at several temperatures.

One hundred five isolates representative of various of the commonly encountered colonies were given a "screening test." Eighty-five of the organisms selected were found to be Gram-negative rods that could be separated into one of three groups according to their ability to attack gelatin as shown in Table 2. These groups, in turn, could be subdivided to some extent

TABLE 2

Grouping of Microorganisms Associated with Slime on Cut-up Chicken (All organisms were of the genus Pseudomonas unless noted otherwise)

Group I. Gelatin liquefied rapidly (1-4 days)		
(a) Dextrose acid; maltose and fructose not acid	(b) Dextrose and fructose acid; maltose not acid	(c) Dextrose, maltose and fructose acid
28 organisms	1 organism	1 organism (Flavobacterium)
(d) Dextrose, maltose and fructose not acid		
3 organisms [c]		
Group II. Gelatin liquefied slowly; incomplete in 60 days		
(a) Dextrose acid; maltose and fructose not acid		
23 organisms		
Group III. Gelatin not liquefied in 60 days[d]		
(a) Dextrose acid; maltose and fructose not acid	(b) Dextrose and maltose acid; fructose not acid	(c) Dextrose, maltose and fructose not acid
27 organisms [c]	1 organism	1 organism (Flavobacterium)

[c] A chromogenic organism (Flavobacterium) has been included in this group.

[d] Cocci found on cut-up chicken also were in this group.

depending upon the ability of the microorganism in question to ferment various carbohydrates. The remaining twenty isolations were cocci or coccobacilli. Screening tests indicated seventeen different biochemical patterns for the types of flora sampled. Thirteen of these were made up of Gram-negative rods (Table 3); the remaining four were cocci or coccobacilli.

Characteristics of Organisms Associated with Sliming of Cut-up Chicken

Code No.	Gram Stain	Size and Shape	Motility	Flagella	Agar Colony	Agar Slant	Liquefaction of Gelatin Stab	Litmus Milk	Dextrose	Maltose	Fructose	Nitrate	Indole	H_2S	Growth at 10° C.	Growth at 20° C.	Growth at 37° C.
6-8	G. neg. rods	Medium; single and in pairs	Motile	Polar	Light buff to yellow; glistening; circular	Buff; smooth; flat; viscid	Stratiform (2); complete (14)	Proteolysis; alkaline	Neutral (2); alkaline (14)	Alkaline (7)	Alkaline (7)	−	−	−	+	++	−
7-1	G. neg. rods	Medium	Actively motile	Polar	Circular; grayish; translucent; glistening	Moderate; filiform; smooth; flat; glistening; creamy	Infund. (4); becoming stratiform; inc. (60); pinkish	Slightly alkaline (4); reduced (60); slight peptonization; slight coagulation	Acid (3); alkaline (14)	Alkaline (7)	Alkaline (7)	−	−	−	++	++	+
7-2	G. neg. rods	Medium; single and in pairs	Motile	Polar	Circular; grayish; translucent; glistening	Moderate; filiform; smooth; flat; glistening; creamy; viscid	Infund. (1); complete (4)	Proteolysis; alkaline (4); complete peptonization (60); slimy	Acid (3); alkaline (14)	Alkaline (7)	Acid (14); alkaline (60)	+	−	−	++	++	+
7-5	G. neg. rods	Medium; single; pairs; clumps	Motile	Polar	Circular; grayish; translucent; glistening	Moderate; filiform; smooth; flat; glistening; creamy; viscid	Not liquefied	Alkaline	Sl. acid (2); neutral (7); alkaline (14)	Alkaline (7)	Alkaline (7)	−	−	−	++	++	++
7-7	G. neg. rods	Medium; single and in pairs	Actively motile	Polar	Light buff	Moderate; filiform to effuse; flat; glistening	Not liquefied	Alkaline (4).	Sl. acid (4); neutral (7); alkaline (14)	Alkaline (7)	Alkaline (14)	−	−	−	++	++	+
7-13	G. neg. rods	Short; in pairs	Actively motile	Polar	Convex; circular; glistening	Heavy; beaded; raised; smooth; glistening; white	Crater (2); becoming stratiform; inc. (60); pinkish	Slightly acid (14); curd acid at top; peptonized	Acid (3); alkaline (14)	Alkaline (7)	Alkaline (7)	−	−	−	++	++	0?
7-18	G. neg. rods	Medium; single and in pairs	Actively motile	Polar		Thin; filiform; smooth; flat; glistening; translucent	Stratiform (1); complete (3)	Proteolysis (2); alkaline (7); complete peptonization and slimy (10)	Acid (2); alkaline (4)	Alkaline (7)	Alkaline (7)	−	−	−	++	++	+
7-19	G. neg. rods	Medium; single and in pairs	Motile	Polar	Convex; circular; glistening; creamy	Moderate; filiform; raised; smooth; glistening; viscid	Not liquefied	Alkaline (4)	Acid (2); neutral (4); alkaline (4)	Alkaline (7)	Alkaline (7)	+	−	−	++	++	+
8F-4	G. neg. rods	Medium; single and in pairs	Motile	Polar	Glistening	Moderate; smooth; glistening; translucent	Complete (4)	Proteolysis (4); alkaline	Alkaline (4)	Alkaline (4)	Alkaline (7)	−	−	−	±	+	−
8-12	G. neg. rods	Medium; single and in pairs	Not motile or sluggishly motile	None		Heavy; filiform to effuse; flat; glistening; viscid	Not liquefied	Slight acid (30; acid (60)	Acid (1); alkaline (30)	Alkaline (14)	Alkaline (30)	−	−	−	+	+	0?
9-10	G. neg. rods	Medium; single and in pairs	Actively motile	Polar	Convex; circular; glistening; creamy	Heavy; filiform; flat; glistening; creamy; translucent	Stratiform (1); complete (7)	Proteolysis; alkaline and complete peptonization (60)	Acid (2); neutral (7); alkaline (14)	Alkaline (4)	Alkaline (7)	+	−	−	++	++	0?
9-16	G. neg. rods	Medium; single and in pairs	Actively motile	Polar	Convex; circular; glistening; creamy; opaque	Heavy; filiform; flat; creamy; translucent; raised	Not liquefied	Alkaline (4)	Acid (2); alkaline (4)	Acid (3); alkaline	Alkaline	+	−	−	++	++	0?
9-18	G. neg. rods		Not motile	None	Entire; flat; yellow; glistening	Moderate; filiform to effuse; flat; glistening	Stratiform (1); complete (3)	Slimy curd; proteolysis (4); alkaline; complete peptonization (60)	Acid	Acid	Acid	−	−	−	0	+	±

Motility tests and flagella stains showed all but two of the Gram-negative rods to be motile and to possess polar flagella. One of the non-motile rods was a deep yellow-buff in color and was found to be a *Flavobacterium*. Nitrate and temperature tolerance studies were used for further differentiation.

There was a slight increase in numbers of chromogens on the poultry stored at 50° F. (10° C.) and possibly at 40° F. but the spoilage organisms developed so rapidly that the percentage of chromogenic forms decreased markedly.

The Gram-negative rods having polar flagella were classed as members of the genus *Pseudomonas*. The principal morphological, cultural and biochemical reactions of the organisms studied are shown in Table 3. Also, the several *Pseudomonas* strains encountered in this study are compared with species identified in Bergey (6th ed.), and important differences indicated (Table 4). The coccus or coccobacillus forms were similar in many respects to *Alcaligenes viscosus* but were spherical or almost spherical, non-motile, and did not produce ropiness in broth.

TABLE 4

Relationship of Organisms Isolated from Slimy Birds with Known Species of Pseudomonas

Strain No.	Species given in Bergey, 6th ed.	Differences from reported species
6-8	Pseudomonas ochracea	Indole, H_2S, glucose not reported (in Bergey, 6th ed.)
7-1	Pseudomonas geniculata	Sugars not reposted
7-2	Pseudomonas mephitica	Reduction of litmus milk, maltose, acid, slow gelatin liquefaction reported; grows at 37° C.
	Pseudomonas putrefaciens	Rapid reduction of litmus reported; sugar reactions not reported
7-5	Pseudomonas sinuosa	Milk reported unchanged
7-7	Pseudomonas-segnis	Indole not formed; sugars not reported
7-13	Pseudomonas fragi Pseudomonas multistriata	Alk. in maltose and fructose not reported Gas from glucose reported
7-18	Pseudomonas pellucida	No reactions reported
7-19	Pseudomonas rathonis	Maltose and fructose not reported
8F-4	Achromobacter pellucidum	Reported no action for dextrose, other sugars not reported. Bergey 6th ed. indicates this organism probably a Pseudomonas
8-12	.....	
9-10	.....	
9-16	Pseudomonas desmolyticum Pseudomonas pictorum	Sugars not reported Fructose not reported
9-18	Flavobacterium lutescens	Nitrates reported reduced

Discussion

A rather heterogenous flora was found on the lean surfaces or skin of eviscerated cut-up birds before storage. Some of the bacteria, such as members of the enteric group, have sanitary and even public health significance. However, at the temperatures of storage employed in this study, these organisms did not keep pace with those responsible for spoilage. Whereas Gunderson, et al. *(5)* isolated coliform bacteria repeatedly from fresh commercial eviscerated fowl, in the present study members of this group were not identified with the development of slime or off-odor at temperatures of 50° F. or below.

The predominating types of flora on slimy birds were quite restricted; the numbers of organisms associated with this condition were enormous. A relationship between the time required for spoilage and bacterial load can be demonstrated by referring to Figure 3. The development of off-odor generally could be detected at the time that small and discrete colonies were observed on the lean surfaces. Shortly thereafter these colonies coalesced to form a more-or-less uniform slimy layer on the piece of chicken in question. From the data collected during this study, the total number of bacteria per square centimeter of surface was found to reach a value of approximately 10^8 before off-odor was evident. When sliming was observed the load was slightly higher (10^8 to 10^9).

The average storage time possible before deteriorative changes became pronounced was found to be dependent not only upon the temperature of storage but also upon the initial amount of bacterial contamination. Birds prepared in accordance with sound sanitary practice invariably had good keeping time while chickens processed by unsanitary methods were shown to develop slime very quickly. As an example of this, it may be seen (Figure 3) that one lot of cut-up fryers, which had an initial load in the millions per square centimeter immediately after processing, kept for less than two days when stored at 50° F., while a very low count experimental sample showed no signs of sliming after storage at the same temperature for four days.

No pronounced differences in type of flora developing or in the time required for multiplication were noted when initial loads were equivalent. The average storage life for commercially eviscerated fresh or frozen cut-up birds when kept at 50° F. (10° C.) ranged between two to three days; at 40° F. (4.4° C.) spoilage before six to eight days was infrequent, and at 32° F. (0° C.) the chicken did not become slimy until it had been stored for fifteen to eighteen days.

In many cases, when the cut-up birds were held at 32° F., the total count decreased during the first few days. Several factors may have been responsible for this initial decline including an unsuitability of the storage temperature for reproduction or survival of chromogens and mesophilic forms and insufficient time for psychrophilic or cold tolerant organisms to come out of the lag phase.

The two types of organisms isolated repeatedly from stored off-odor slimy chicken were representative of the genera *Pseudomonas* and *Alcaligenes*. Members of the former genus were the more commonly encountered. While coccoid forms were occasionally shown to persist on slimy birds, they were rather unreactive biochemically. The role played by these latter organisms in this spoilage condition could not be determined. It is possible that through concomitant action with the more proteolytic *Pseudomonas* strains, members of the genus

Alcaligenes may be important in the overall decomposition of poultry.

According to reports of previous workers [Haines *(6)*, Empey and Vickery *(1)*, and Moran *(14)*], these "cold-temperature" organisms have an optimum temperature for growth at about 68° F. (20° C.) and will grow down to about 26.4° F. (—3° C.) [Haines *(8)*]. A record kept of the one hundred five organisms isolated from plates made from slimy birds did not indicate those species reproducing at 32° F. to be unlike those responsible for spoilage at 50° F.

The property of many of the various *Pseudomonas* strains to product acid from dextrose but not other sugars would seem to indicate that they are closely related species. On the other hand they can be subdivided into at least three groups depending upon their ability to liquefy gelatin. The various species encountered have been keyed to show a relationship with organisms shown in Table 4. The important differences between the strains isolated and previously identified species have been indicated. Classification of bacteria responsible for slime as members of the genus *Pseudomonas* is not necessarily in conflict with findings of earlier workers, Haines *(6, 7)*, Empey and Vickery *(1)*, Moran *(14)* and Lochhead and Landerkin *(9)*, who placed similar organisms in the genus *Achromobacter*. Changes in classification in Bergey (6th ed.) subsequent to their work have resulted in the transfer of several related species from the genus *Achromobacter* to the genus *Pseudomonas*. Also, it might be appropriate at this time to point out that the sugar reactions given in Bergey for those species of *Pseudomonas* that had been classified are grossly incomplete. Results from this study indicate that almost every one of the strains selected for detailed biochemical tests gave an acid reaction in dextrose initially but, after further incubation, underwent alkaline reversion. Typical reactions for the same organisms in fructose and maltose were generally alkaline by the seventh day when phenol red was employed as an internal indicator.

Empey and Vickery *(1)*, Mallman, Zaikowski and Ruster *(12)* indicated that flora developing on cold storage beef were largely soil organisms coming from the hoofs and hides of the animals. Organisms associated with feathers, feet and feces of birds may be considered in a similar manner. Then, in view of the relationship between initial contamination and sliming, the sanitary practices adopted in the processing plant during scalding and eviscerating the birds pre-determine its storage life.

Summary

A characteristic off-odor, accompanied within a short time by the development of a bacterial slime, has been observed repeatedly on cut-up eviscerated chicken stored at refrigerator temperatures above freezing. This condition was associated with the growth and coalescence of colonies of several species of *Pseudomonas*. Typical growth curves were obtained for these bacteria by swabbing definite surface areas of chicken thighs at critical intervals during storage and making plate counts of appropriate dilutions. These organisms were capable of comparatively rapid growth at 40° F. (4.4° C.) and at 50° F. (10° C.) and showed appreciable multiplication even at 32° F. Average storage times before evidence of deteriorative changes became marked for commercial fresh and defrosted-frozen chicken were 2-3 days at 50° F., 6-8 days at 40° F. and 16-18 days at 32° F.

The initial bacteriological quality of the chicken was shown to have great effect on its storage possibilities. Birds prepared in accordance with sound sanitary practice invariably had good keeping time.

Immediately after processing chromogenic bacteria represented 50-60%, *Pseudomonas*, colorless cocci and closely related forms 20-25%, and miscellaneous bacteria accounted for the remaining 20-25% of the contaminative load. At the end of the storage period it was found that chromogens and miscellaneous forms represented less than 1% of the total flora. *Pseudomonas*, and to some extent, Gram-negative cocci or coccobacilli, were present exclusively at that time.

The total number of microorganisms growing on the surface was found to reach a value of approximately 10^8 before off-odor or sliming were evident.

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Effect of Temperature and Exposure on the Peeling of Fruits and Vegetables[a]

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Experiments were conducted on the effect of temperature and exposure on the peeling characteristics of fruits and vegetables. It was found that, as the exposure temperature was increased, exposure time could be reduced and peeling improved. It was also found that the product absorbed less heat in the process.

The investigation which forms the subject of this paper was undertaken at the laboratory of the Atlas-Pacific Engineering Co. Inc. of Emeryville, California, with the object of determining the effects of elevated temperatures obtained by superheating steam, on the peeling of fruits and vegetables so treated.

The results will be treated from the standpoint of the mechanics of steam peeling only, and the data will be presented as observed during the course of the tests purely from an engineering point of view.

The problem involved the study of the effect of temperature and exposure on peeling and heat absorption, in the presence of super-heated steam vapors. Tests were secured to simulate conditions which would be encountered in practice. To this end, equipment was designed and built, consisting of a closed, insulated tunnel through which the products passed on a conveyor, with sealing means at entrance and exit to prevent the escape of steam, and heating surfaces and steam orifices directly over the conveyor and product. A variable speed drive was used on the conveyor in order to effect accurate exposure control.

As present methods of steam peeling are limited to the temperatures available by either resorting to pressure vessels in order to secure temperatures over 212° F. (100° C.) or the use of throttling of steam from house pressure (usually 125 psig.) and passing the throttled steam over closed coils under pressure in order to obtain steam at atmospheric pressure at temperatures in excess of 212° F., a special steam superheater was designed capable of raising the steam temperature to any desired value up to 950° F. (510° C.). The firing rate of the superheater was controlled by steam temperature, and the tunnel temperature controlled by the rate of steam admission to the superheater. Figure 1 shows a schematic diagram of the steam circuit.

The equipment utilized steam under usual cannery steam conditions at pressures from 80 to 175 psig. whichever was available. A steam separator was used to remove moisture entrained in the steam from the house supply. This provided dry saturated steam which was then superheated in the first stage of a two-stage superheater to the desired temperature, 950° F. (510° C.)

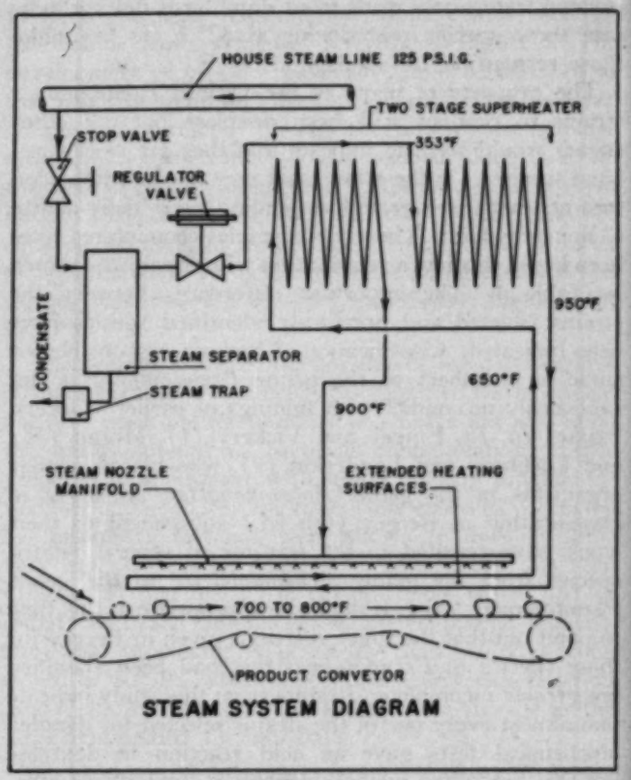

FIG. 1.

or over. This high temperature steam was passed through a series of extended heating surfaces which was placed directly over the product conveyor in the insulated tunnel.

Due to the heat absorption by the product and other losses, the steam left the surfaces at approximately 650° F. (343.3° C.). Steam was then returned to the second stage of the superheater and again raised to approximately 900° F. (482.2° C.) and passed to the steam orifices or nozzles directly over the extended surfaces onto the product moving on the conveyor directly below. This method provides a uniformly high temperature atmosphere and accurate control of both steam temperature and the temperature of the tunnel atmosphere.

As present peeling methods for tomatoes utilize steam at temperatures from 240° F. (115.5° C.) to 300° F. (149.9°C.) obtained either by the use of pressure vessels or superheating by throttling to atmospheric pressure as indicated previously, we chose to start our investigation at a lower limit of temperature of 300° F. (149.0° C.) in the tunnel at atmospheric pressure. Exposure time was held constant at 50 seconds, and the temperature increased by 50° F. intervals to an upper limit of 650° F. (343° C.). From 300° F. to

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 14, 1949. Published wih permission of Atlas-Pacific Engineering Co., Inc., copyright owner.

450° F. (149 to 232.2° C.) tomatoes could be slip peeled although the skin was not broken in most cases. The skin was thick, and there was adherence on most samples. Improvement could be noted at each increase in temperature. In the range between 475 and 650° F. (246 to 343° C.), many samples were completely peeled as they emerged from the high temperature tunnel, and those which were not had the skin broken in many places, greatly facilitating hand peeling. The results of higher temperature indicated that shorter exposure could be used to advantage.

This was promptly investigated and samples of tomatoes were run at temperatures up to 850° F. (454.4° C.) and exposure time down to 8 seconds. Very good results were secured at exposures of 8 to 12 seconds at 800 to 850° F. (426.7 to 454.4° C.). The skin removed was much cleaner than before, there being no adherence, and the fruit itself remained very firm. There was only very minor evidence of heat penetration at the higher temperature and short exposure, and the color bearing layer remained firm and intact. These tests were subsequently repeated and verified. In many cases, the peel was completely removed and emerged from the tunnel entirely separated from the fruit, requiring no additional washing. The best results were obtained when the tomatoes were cored prior to exposure.

Other products tested were pears, carrots, new and old potatoes, bell peppers, red beets and onions. Each product, of course, required different conditions. Pears showed best results at 700 to 750° F. (371 to 399° C.) at an exposure of 15 to 20 seconds. Carrots at the same temperature with an exposure of 50 to 60 seconds. Old potatoes at 700° F. (371° C.) 80 seconds. New potatoes 650° F. (343° C.) at 80 seconds. Bell peppers at 750° F. (399° C.) at 180 seconds. Exposure time on all of the above can be further reduced by increasing the temperature, as will be shown later. Equipment is now under construction which will permit operation between 850 and 1000° F. (454.4 to 537.8° C.).

Heat absorption by the product during the peeling operation is an effect incidental to the operation but should be held to an absolute minimum due to its malicious action on quality and physical appearance. Product heat absorption is dependent upon factors including exposure temperature, exposure time, the nature of the skin, its texture, thermal conductivity and specific heat of the skin and fruit. All of the above will determine peeling time and temperature.

Applying a theoretical approach, the heat absorbed by the product in a typical steam peeler is usually by both convection and radiation: convection by the fact that the product is moving in a high temperature atmosphere and is subjected to the impingement of steam issuing from orifices or nozzles, and radiation by the fact that the product is moving under a surface which is at a much higher temperature than the product. Conduction was mentioned previously. Heat transfer by conduction through the skin should be limited to the thickness of the skin.

The elementary equation for convection is $q = UA(\Delta t)$. Where q is Btu per hour, U is the overall film coefficient, A is the total surface subject to convection in square feet and Δt is the temperature difference between the product and the surrounding atmosphere in ° F. Now let us change q to q_1 which is the total heat absorbed and multiply the right hand factor by "n" which we can call the time factor or exposure. The new equation is now $q_1 = UA(\Delta t)n$. We can see that the total heat absorbed is directly proportional to $(\Delta t)n$. Assuming that UA is approximately constant for all practical purposes, then as the value of t is doubled, for a given value of q_1 the exposure time factor is halved.

Now let us look at the effect of radiation. Using the familiar general equation for radiation, and combining shape factor, radiant area and emissivity into a single expression "K," then the equation is

$$q = K\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

Where again q is in Btu per hour, T_1 is the absolute temperature of the radiation surface and T_2 the absolute temperature of the absorbing surface. Note that q is directly proportional to $(T_1^4 - T_2^4)$. As an example, assume a temperature T_2 of 100° F. (560° abs. 37.8° C.) for each case. If the temperature difference is increased from 300 to 600° F. (148.9 to 315.5° C.), for a given value of heat absorption "q," the time factor "n" can be reduced to approximately one-fourth of its original value.

The relative effectiveness of radiation and convection on the product will vary considerably. Radiation will be affected by the temperature difference between the radiating surface and the absorbing surface and their relative position. Convection will be affected by the speed of the product through the tunnel and the mass flow rate of steam around the product as well as the difference in temperature between the surrounding atmosphere and the product. In low temperature equipment, convection will probably predominate due to the relatively lower temperature of radiating surface and the high rate of live steam flow around the product. In high temperature equipment the effect of radiation will be more pronounced due to the higher radiation surface temperature.

In the equipment used in these tests we can say that the two effects were approximately equal and that the combined effect caused a reduction in exposure time factor of 75 to 80% by doubling the operating temperature difference in ° F. between surfaces and atmosphere and the product. The effect of exposure temperature on exposure time for tomatoes is shown graphically by Figure 2. All points on this curve represent conditions under which peeling of various degrees was possible. By this is meant that for a given temperature condition, an exposure time increase over the amount indicated would not serve to improve peeling, but would only increase heat penetration. In other words, under the low temperature portions of the curve the tomato skin was loose but perhaps not broken, and the tomato could be slip peeled and any further exposure would not improve the peeling condition. Under the

higher temperature portions of the curve the tomato skin was broken in many places and in many cases off altogether and therefore longer exposure than this would be of no use. The curve of Figure 2 is then intended to indicate maximum conditions for peeling. It will be noted that the peeling time for the 400° F. (204.4° C.) condition is 62 seconds and for the 800° F. (426.7° C.)

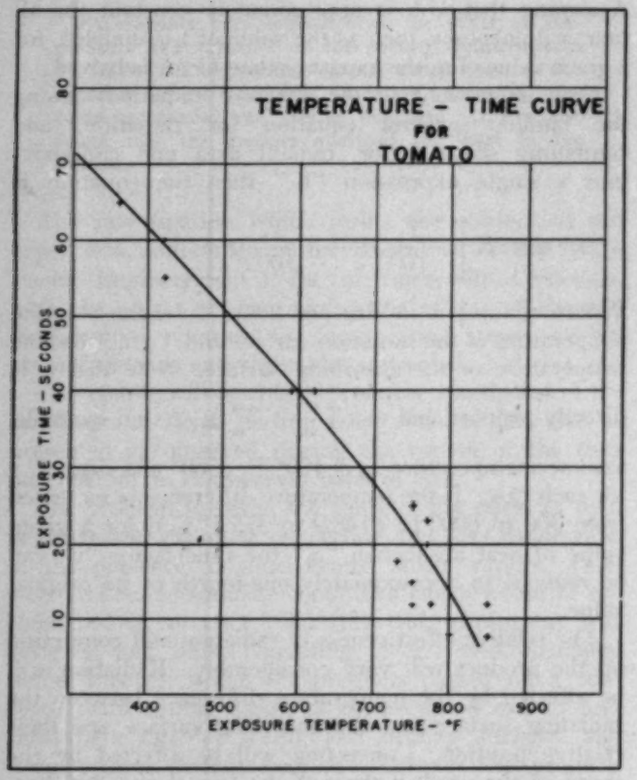

FIG. 2.

condition 14 seconds, or a reduction of 77% in the exposure time.

It was noted also that at the low temperature condition the skin was broken in but one place and that the tomato could be slip peeled although it indicated considerable evidence of heat penetration. Longer exposure than that necessary to break the skin only serves to increase damage by heat penetration. At the high temperature short exposure conditions from 650° F. (343.3° C.) and up, the skin was broken in many places and was either entirely off as the fruit emerged from the tunnel, or could be washed off. Heat penetration was almost entirely absent and this was particularly noted at the 800° F. 14 second condition. The product emerged from the tunnel cold at the core, and with heat penetration only through the skin. A measurement by Iron-Constantan Thermocouple and Millivoltmeter was taken immediately under the skin of a tomato which had been subjected to a temperature of 770° F. (410° C.) for 23 seconds and indicated an average temperature in that area of 130° F. (54.5° C.), although the outside skin temperature had been much higher. It is recognized that the actual temperature at this point dropped somewhat during the course of the measurement, however, very fine thermocouple was used, and the instrument reading rose to its highest value within a few seconds. With an atmosphere temperature of 770° F. (410° C.) and a temperature under the skin of 130° F. (54.4° C.) allowing a steam film temperature drop of 150° F., a possible temperature difference of 490° F. could be obtained across the thickness of the skin momentarily.

Figure 3 is a curve of Heat Absorption in Btu per pound of product vs. an exposure-temperature factor, Degree Seconds, which was selected as a convenient basis for comparing the results. Degree Seconds is exposure time in seconds multiplied by exposure temperature in ° F. The higher portions of the curve are for low temperature long exposure conditions, and the lower portions for high temperature short exposure conditions. This curve indicates graphically what happens in a steam peeler when temperature is increased and exposure decreased. Again, this curve represents conditions under which peeling was possible, otherwise, the values of exposure factor would of course have little meaning as regards practical application. As an example, at an exposure factor of 22 x 10^3 degree seconds, the heat absorption by the product is 44.6 Btu per pound, and at 14 x 10^3 degree seconds, 33.0 Btu per

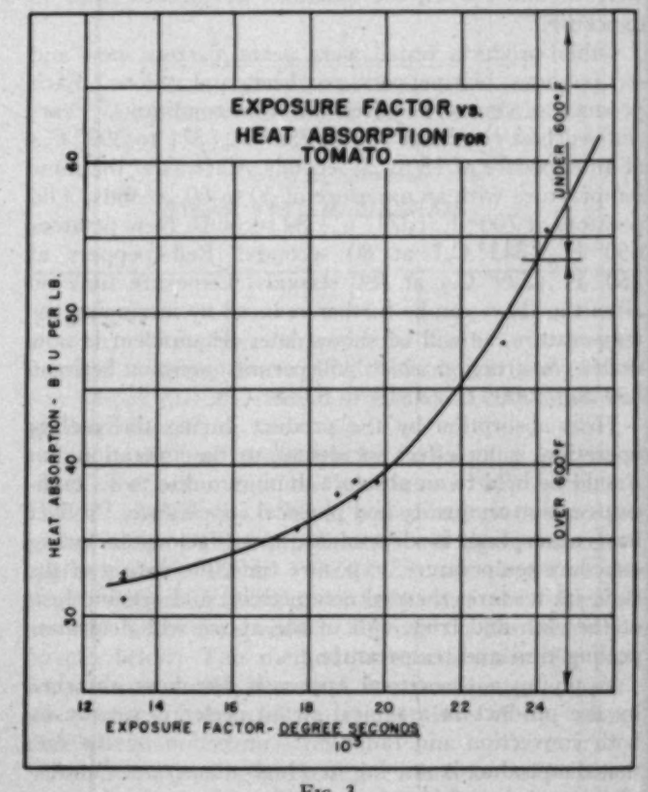

FIG. 3.

pound, or a reduction in exposure factor of 36% produces a reduction of 26% in heat absorption. The first (lowest) test point on the curve is at 730° F. 18 seconds. Other products will be similarly affected but to a different degree, as explained before.

The test points for tomatoes in Figure 2 plotted on semi-log coordinates becomes for all practical purposes

a straight line. Taking test points for other products, a chart of probable temperature-exposure characteristics can be obtained. It is interesting to note what might be done by extending the lines into the higher temperature regions. This is shown in Figure 4.

All of the results recorded here were obtained without the aid of caustic dip or spray. Some tests were conducted, however, on tomatoes, potatoes, and carrots using a caustic dip prior to treatment at high temperature. The results obtained were not conclusive and did not indicate that improvement could be effected by the use of such materials as compared with the use of higher temperatures. However, more research is planned along these lines.

Preliminary work has also been done on citrus. Encouraging results are indicated at 50 to 60 seconds at 750 to 800° F. (398.9 to 426.7° C.) on oranges. The peel must be scored mechanically prior to temperature treatment although the peel does break without scoring at sufficiently high temperatures and better results are anticipated when higher temperature equipment becomes available. During the treatment the peel shrinks and becomes loose and can easily be removed either by hand or by mechanical means. The treatment of citrus requires further investigation.

The high temperature treatment of peaches and apricots is now under investigation. Data on these will be available in the near future.

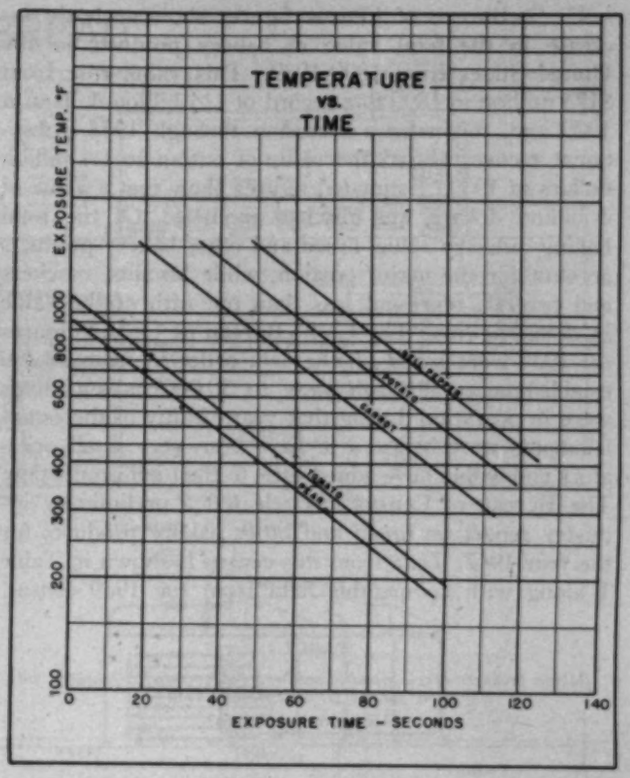

FIG. 4.

Industrial and Production Trends in the Baking Industry*

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Industrial and production trends in the baking industry are discussed with the aid of illustrations. The paper is divided into four parts which treat successively the growth of the industry, production methods employed in basic types of bakery products, formula developments and new trends in processing and packaging. The final section includes many new developments and techniques such as bulk handling of flour and other dry ingredients, prepared mixes, enrichment, active dry yeast, pan glaze, cross graining, improved packaging, frozen bakery goods, applications of radio-frequency heat and several others.

Introduction

The baking industry, as a modern industry, has shown a steady development within the past 50 years. Although the occupation of baking is among the oldest, it was the adoption of mass-production and mass-distribution methods that made possible the lower cost of bakery products and led to the growth of commercial baking and the steady decline of home baking.

Currently, the production value of the baking industry in the United States is estimated at approximately 3 billion dollars annually. In an industry having an annual value of 3 billion dollars, new industrial and production trends are likely to develop, and exert their influences on the industry.

In order to discuss industrial and production trends in the baking industry, it seemed desirable to trace the development of the industry. This paper, therefore, has been divided into four parts; namely, (1) growth of the industry; (2) production methods employed in basic types of bakery products; (3) formula development; and (4) new trends in processing and packaging. In order to avoid being time-consuming, we have resorted to many illustrations. Instead of speaking in detail about production methods, flow-sheet diagrams are used to elucidate that part of the paper.

Part 1: Growth of the Industry

The total baking industry includes all types of breads, rolls, coffee cakes, soft cakes, handmade cookies, pretzels, pastries, pies, doughnuts, crullers and other fried cakes, crackers and biscuits. Most breads, rolls and some products like yeast-raised doughnuts and coffee cakes are yeast-leavened, whereas most cakes, cookies, crackers, biscuits and pretzels are chemically leavened.

* Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 12, 1949.

U. S. Bureau of Census figures show a steady increase in the total value of bakery products in the United States from 1899-1939. This value rose from $175 million in 1899 to a record of 1½ billion dollars in 1929 and, following a recession through 1933, subsequent recovery lifted the value of output to 1.4 billion dollars in 1939. Estimated figures show that a value of 3 billion dollars was reached in 1946. Of the total baking industry value, bread and other bakery products account for the major portion, while biscuits, crackers and pretzels represent less than one-fifth of the value in dollar figures. The U. S. Bureau of Census figures for 1939 were based on the data collected from 18,399 establishments although close to 30,000 baking shops were in operation during that year. Many of the establishments were believed to have been very small operators and would have added little to the total production. The Bureau of Census has released a preliminary industry report on bread and other bakery products for the year 1947. Data from this census is shown in Table 1 along with comparable data from the 1939 census.

TABLE 1

Baking products (excl. biscuits, crackers and pretzels): Quantity and value for the U. S. 1947 and 1939 [b]

(All figures in millions)

Product	1947		1939 [c]	
	Quan.	Value	Quan.	Value
Bakery Products Total	....	$2,361	....	$1,183
Bread (lbs.)	10,525	1,186	9,413	657
White Pan (lbs.)	8,520	937	7,219	492
White Hearth (lbs.)	307	38		
Whole Wheat, Cracked Wheat and other Dark Wheat Breads (lbs.)	893	105	1,731	128
Rye, Incl. Pumpernickel (lbs.)	613	78		
Raisin and Other Specialty Breads (lbs.)	192	28	463	37
Other Perishable Bakery Goods	....	1,000	....	500
Rolls, Bread Type (lbs.)	943	153	1,068	140
Sweet Yeast Goods (lbs.)	612	182		
Doughnuts, Cake Type (dozens)	252	80	336	55
Soft Cakes (lbs.)	1,210	391	953	186
Pies (lbs.)	601	147	....	75
Pastries, All Types	....	22	....	24
Cookies, Handmade (lbs.)	81	25	112	20
Bakery Products Not Reported in Detail	....	175	....	26

[b] Figures from U. S. Bureau of Census, Preliminary Industry Report, Bread and other Bakery Products for 1947.

[c] 1939 data are not strictly comparable with 1947 because the production of bakeries primarily engaged in selling bread goods through a single retail outlet was included in 1939 but not in 1947. It is estimated that the 1939 figures are overstated by approximately 10% for that reason.

The 1947 census excludes the one-store retailers and also such products as biscuits, crackers and pretzels. The value for biscuits, crackers and pretzels amounted to approximately 201 million dollars in 1939. Those bakers who sell primarily to grocers and restaurants, chain store bakers, multiple unit retailers and house-to-house bakers are included in the 1947 census.

Although the baking industry is one of the most extensive users of labor saving equipment, it is the largest employer in the various food industries. In 1849 there were approximately 7,000 persons associated with the baking industry. According to U. S. Bureau of Census figures for 1939, the 18,399 establishments employed approximately 231,000 wage earners. The 1947 census reports 6,797 establishments and 233,310 employees as an average for the year.

Since 1910, the increase in consumption of commercial baked goods has been a record accomplishment for the baking industry. Figure 1 illustrates how wheat

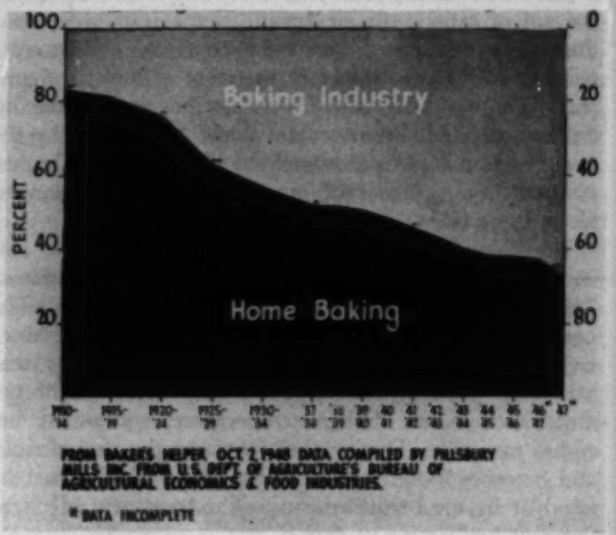


FIG. 1. Total wheat flour consumption — Baking industry versus home baking.

flour consumption in the U. S. has changed hands. From 1910-1914, the baking industry consumed only 16.2 percent of the wheat flour while home baking accounted for 83.8 percent. A steady increase, with the baking industry gradually capturing more and more business from home baking, shows that in 1947 approximately 68 percent of the wheat flour was consumed by the baking industry and home baking had declined to a utilization of about 32 percent of the wheat flour.

During the years 1914-1947, production, man-power, and value in the baking industry have shown an increase. However, a steady decline in the total per capita of wheat flour consumption happened during this same period. This decline is undoubtedly due to advances in other food industries which have made it possible for the average American citizen to presently thrive on a well-balanced diet and consume a variety of foods year-round which at one time were only available during certain seasons.

For those engaged in the baking business, regional and city size differences in bakery buying habits are of interest.[cc] The "average" American family spent approximately 99 cents weekly for baked goods during 1947. The eastern family spent the highest amount of $1.27 weekly and the southeast the lowest with 70 cents. Although regional bakery buying habits differ, bread, cake and cookies were the three main items purchased in all sections of the country. In large cities, families ate less bread and rolls and spent only 53.7 cents per week for plain goods. The greater availability of sweet goods in the larger cities probably accounts for the larger purchases there. Taste preferences also vary in different

[cc] Following figures from *Baker's Helper*, Oct. 30, 1948. General Mills Survey.

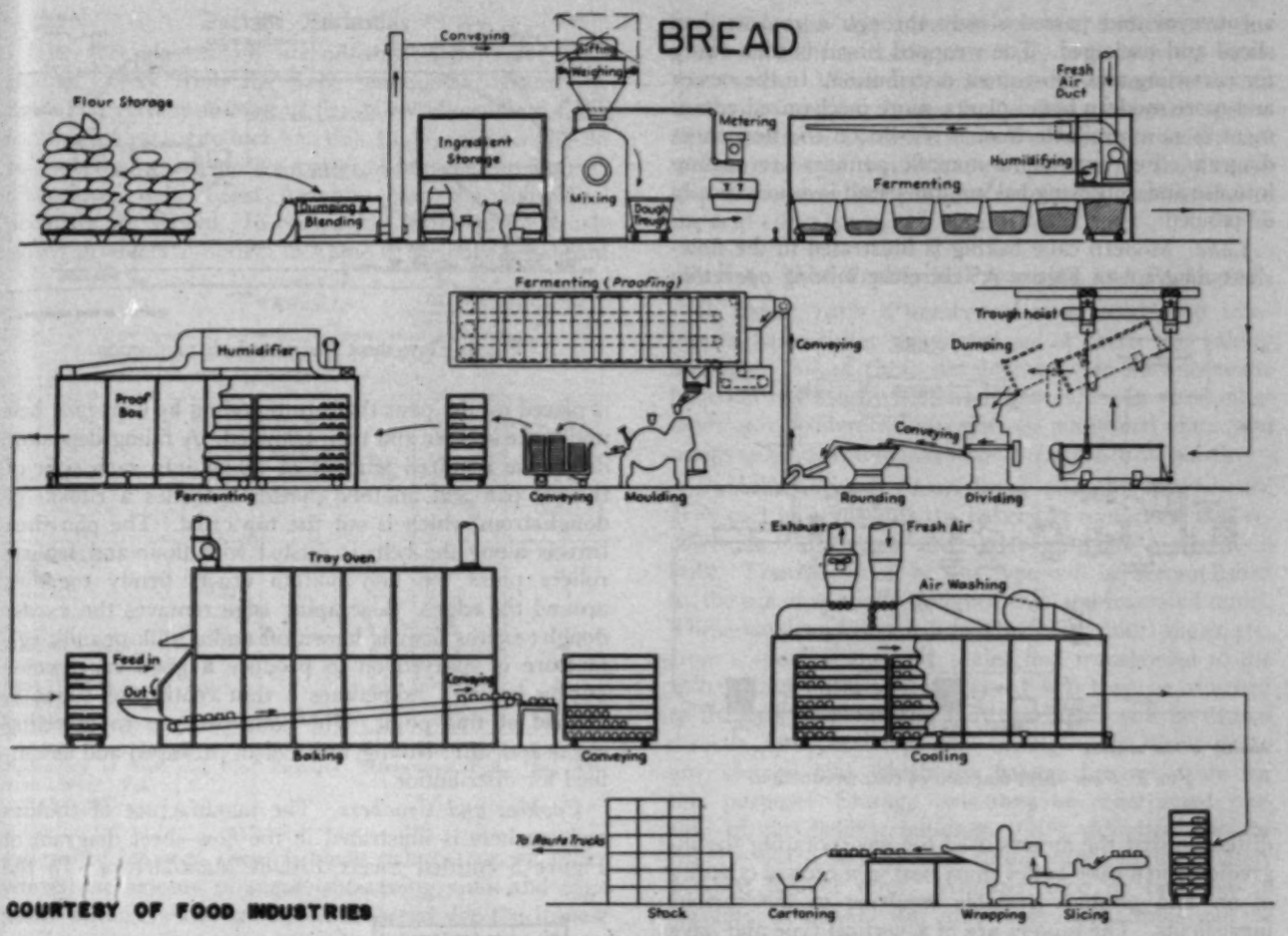


FIG. 2. Flow-sheet diagram of bread production.

sections of the country. Rye bread is more popular in the East while whole-wheat bread is purchased to a greater extent in the West. More bread was sold on the farm and in the West. Although farm families concentrate their home baking mostly on plain goods, they spent 65.2 cents of the bakery dollar for these same items. Despite all the home baking that farm families do, it is interesting to note that they spent 78.4 cents per week for baked goods.

Part 2: Production Methods

This section of the paper is concerned with the mechanized production methods essentially adhered to in large bakeries. Since hand methods are used mostly in small retail bakeries which produce a relatively small volume of all bakery products, these methods are not considered.

The easiest way to describe several of the production methods used according to type of product is through the aid of flow-sheet diagrams.

Bread. Figure 2 illustrates a typical flow-sheet diagram for bread manufacture in the larger mechanized bakeries. Since the principal ingredient in bread is flour, special equipment is needed for handling the large volume of flour that must go into every batch of bread. The flour, in bags, is stacked on skids and can be removed easily for emptying into a blender. The flour is automatically carried to a hopper above the mixer and sifted and scaled directly into the mixer. It is common practice to meter the water; other ingredients such as sugar, salt, yeast, etc. are weighed in proportion to the quantity of flour and added through the top of the mixer. In some cases ingredients are dumped into a mixing tank with some of the water and pumped into the mixer. The giant mixers, used in large bakeries, handle up to 1600 lbs. of dough. Following mixing, the sponge dough is expelled into troughs and placed in a fermentation room controlled at approximately 80° F. and a relative humidity of 75%. After the sponge dough has been fermented (4 to 5 hours) it is remixed with the remaining ingredients and passed through a divider machine which divides the mass into small pieces which are, in turn, conveyed to a rounder that rolls them into spherical units and then on to an overhead proofer. The overhead proofing time may range between 12-15 minutes at which time the dough units are passed to a molder and shaped for panning. Following panning, the racked sets of pans containing the dough pieces are placed in a proof box where the temperature is 94° to 98° F. and the relative humidity approximately 85%. After a suitable pan proof interval, which may range from 60 to 70 minutes, the doughs are fed to a traveling hearth or tray-type oven (tray-type oven is shown in diagram) and baked for 30-35 minutes at 450-500° F. Following baking, the bread is dumped from the pans on

a conveyor and passed slowly through a cooler; then sliced and packaged. The wrapped bread is then ready for cartoning and subsequent distribution. In the newer and more modern bread plants, more mechanized equipment is now available than is shown on the flow-sheet diagram. For example, automatic panners are coming into use and, following baking, the bread is automatically de-panned.

Cake. Modern cake baking is illustrated in the flow-sheet diagram of Figure 3. Here the mixing operation

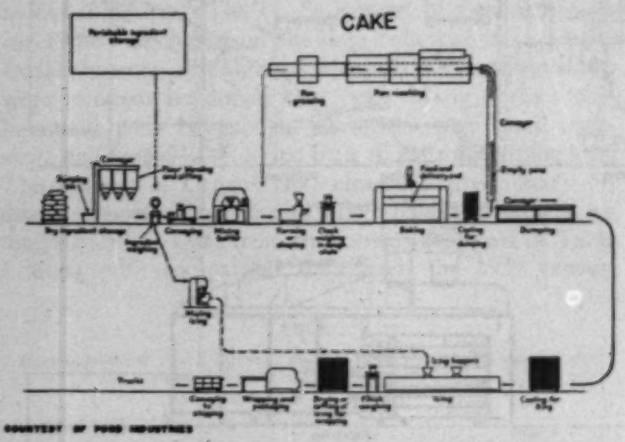


FIG. 3. Flow-sheet diagram of cake production.

differs in that the mixers used for incorporating the ingredients in a cake batter must beat in a certain quantity of air and produce a stable emulsion of the various ingredients. The mixers are of a vertical type and have a paddle which provides creaming and beating action. Following mixing, the batter is transferred to a depositor (indicated as a forming or shaping unit) which automatically deposits the proper quantity of batter in the cake pans as they are passed underneath. By means of different separators in the depositor and the use of different types of dies, batter can be deposited in all shapes of pans. The pans containing cake batter are then placed on racks and taken to the oven where they are baked. The ovens are similar to those used for bread. Following baking, the cakes are cooled in a manner similar to that of bread and are ready for icing. The icing of cakes, such as round cakes, requires some handwork but square or rectangular-shaped cakes can be handled by machine. The icing machine deposits a sheet of icing on top of the cake. The icing is allowed to set for a short time and the cakes are then wrapped and conveyed to a distribution center.

Pie. The essential features of pie baking are shown in the flow-process diagram of Figure 4. The pie dough ingredients are mixed in a special Artiflex-type mixer which imparts a gentle kneading action to the formed dough. It is then refrigerated for 18-24 hours before using. The fruit is first inspected and then cut up and mixed with the proper amount of sugar, starch and water. After cooking, it is cooled and held in refrigerated storage. In the make-up process, the dough is passed through chutes to the sheeting machines and a continuous ribbon of dough, which is the bottom crust,

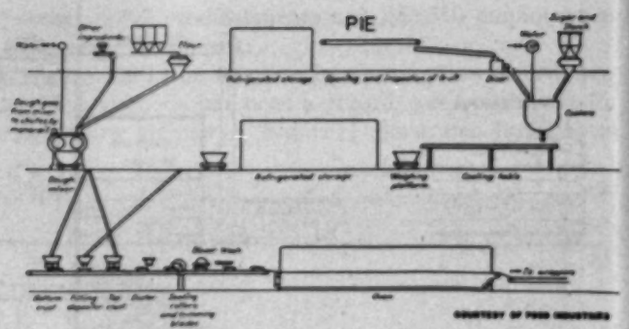


FIG. 4. Flow-sheet diagram of pie production.

is placed on the pans that are traveling by conveyor belt under the sheeter and then trimmed. A filling depositor drops the required amount of filling into each unit of the pie pan and another sheeter extrudes a ribbon of dough from which is cut the top crust. The pan then travels along the belt, is dusted with flour and sealing rollers press top and bottom crusts firmly together around the edges. A scraping edge removes the excess dough; excess flour is blown off and a milk or milk-egg mixture is sprayed on to produce a good crust color during baking. Sometimes a thin coating of sugar is applied at this point. The pans pass on to traveling ovens and, after baking, are cooled, packaged and assembled for distribution.

Cookies and Crackers. The manufacture of cookies and crackers is illustrated in the flow-sheet diagram of Figure 5 entitled Sweet Biscuit Manufacture. In the

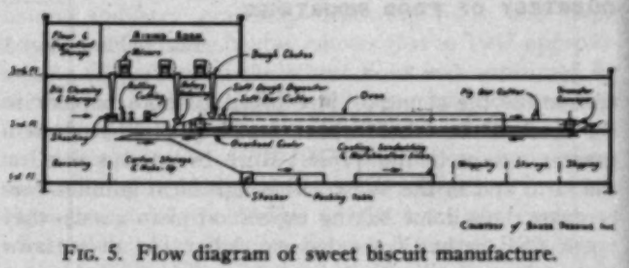


FIG. 5. Flow diagram of sweet biscuit manufacture.

case of some crackers which are produced like bread by a sponge and dough method, the sponge, following mixing, is fermented for approximately 24 hours and then remixed into the dough and given an additional short fermentation. The dough is then rolled out into a continuous sheet and passed through a cutting machine which cuts it into the shape of cracker desired. The cut dough is then passed through continuous band ovens which are similar to the traveling ovens used for bread except for being narrower and longer. The crackers are baked at temperatures from 500° to 525° F. After baking, they are passed through an overhead cooler and then stacked, packed in cartons and wrapped. With sweet biscuit manufacture, the fermentation process is eliminated. Depending on the type of product being manufactured, the dough can be subjected to several variations prior to baking such a rolling, depositing, cutting and rotary embossing. An extra operation is added prior to wrapping for sweet biscuits which require coating and sandwiching.

Part 3: Formulas

The formulas which are illustrated here are considered solely from the basic standpoint. Naturally, there is a certain amount of flexibility allowable for the formula of each product but this slight variance would be superfluous and more a matter of personal preference. Therefore, only basic formulas for the individual products are shown. In comparing formulas for yeast-raised products as shown in Table 2, the only significant difference between them is their richness or, in other words, the amount of sugar, shortening, milk and eggs used. Crackers and whole-wheat bread are the leanest products with average white bread having more sugar and, in addition, some milk. Rolls contain more shortening, sugar and milk than white bread. Sweet-yeast raised products are the richest and, besides, contain still more sugar, shortening and milk; they also have eggs added. As richness increases, yeast content must be increased to give the desired fermentation.

TABLE 2[4]

Comparison of formulas for yeast-raised products.

Figures are percentages on basis of flour as 100%
Only basic ingredients shown

Ingredient	Crackers	Whole Wheat Bread	White Bread	White Rolls (Dinner and Hamburger Rolls, etc.)	Sweet Yeast-Raised Products (Sweet Rolls, Coffee Cake, etc.)
Flour (Diastated)	100	100	100	100	100
Water	56	66	62	64	60
Yeast	0.125	2	2	3	6
Salt	1.75	2.25	2.25	2.25	2
Sugar	1*	4	6	8	14
Milk (Dry Skim)	0	0	4	5	6
Shortening	5	4	4	8	12
Eggs (Whole)	0	0	0	0	10
Dough Conditioners	0.1-0.3	0.2-0.4	0.2-0.5	0.2-0.5	0-0.25

[4] Based on Cathcart, W. H., in Jacobs, M. B., Ed. The Chemistry and Technology of Food and Food Products. Interscience Pub., Inc., New York (1944). Vol. 1.

* Optional.

The typical cake formulas shown in Table 3 are also basic. Actually there are only four different types of cake and these are pound, layer, sponge and Angel food. The pound, layer and sponge cakes can be made with either less sugar or more sugar than the weight of the flour used. With other cakes, many variations of these basic formulas are obtained by the addition of ingredients such as cocoa, chocolate, various fruits, nuts, flavors, etc. When incorporating these variations into the basic formulas, it may be necessary to make special adjustments or modifications. For example, additional moisture may be required to compensate for the absorption of cocoa and the pH may require adjustment due to the acid effect caused by natural fruits, etc.

Part 4: New Trends in Processing and Packaging

In recent years a number of new trends and techniques have either originated in or from the baking industry. All of these developments or advancements have not necessarily been used generally. In some other cases a considerable amount of additional data and usage is needed to substantiate their practical worth.

Bulk Handling of Flour, Sugar and Dry Ingredients. It is said by some that the bakery of tomorrow will receive its flour, sugar and other granular products in bulk. Transportation of this type will be accomplished by the use of specially designed cars and insulated tanks. These tanks and cars will be filled with flour, sugar, etc. from a spout at the mill, sealed and transported to the bakery door. Suction equipment will then be attached to the cars or tanks and the ingredients will be drawn directly into receiving bins through pipe lines or to any storage bins which the bakery has set aside for this purpose. Storage bins may be constructed outside of the bakery building. Cars designed for the bakery which has its own siding carry approximately 140,000 lbs. of flour. Another type of tank has a capacity of 25,000 lbs. and three such tanks can be mounted on a flat railroad car. This type of tank is designed for bakeries which do not have a railroad siding and such tanks are transferred by truck from the railroad car to the bakery. In Figure 6, the overall operation of the bulk handling system is shown diagrammatically. A few large users of flour are currently experimenting with the bulk car system.

Another semi-bulk system designed for the bulk handling of flour or other dry ingredients which is being tried by some large baking concerns is through the use of Tote containers. These containers consist of aluminum bins holding approximately 3,500 lbs. of flour. The flour is placed in the bin at the mill, sealed and shipped

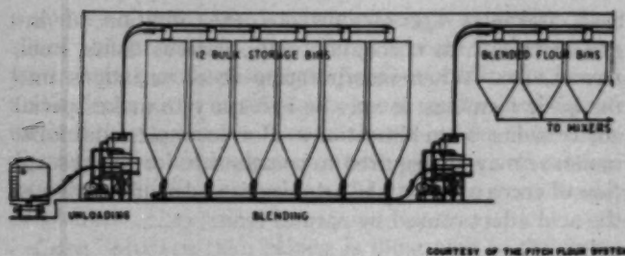
TABLE 3[5]

Typical Cake Formulas

Figures represent Percent on Basis of flour 100%

Ingredient	Original Pound	Modern Hi-Sugar Pound	Low-Sugar Layer	Modern Hi-Sugar Layer	Modern Sponge	Modern Angel Food	Cookies
Flour	100	100	100	100	100	100	100
Butter and/or Shortening	100	60-70	35-45	45-55	0	0	12-50
Sugar	100	120-130	80-100	120-140	110-120	300	50-90
Eggs (Whole)	100	70-75	40-50 or 40-50	55-70 or 55-70	65-75	0	8-20
Eggs (Whites)	0	0	0	0	0	300	0
Eggs (Yolks)	0	0	0	0	45-55	0	0
Milk (Liquid)	0	55-60	50-60	90-95	0	0	0-15
Salt	0	3.0-3.5	2.5-3.0	3.0-4.0	2.0-3.0	4.0-5.0	0.5-1.0
Baking Powder	0	0-2	2-4	4-6	2-3	0	0.5-1.5
Ammonium Bicarbonate	0	0	0	0	0	0	0.5-1.0
Bicarbonate of Soda	0	0	0	0	0	0	0.5-1.0
Cream of Tartar	0	0	0	0	0	4-5	0

[5] Based on Cathcart, W. H., in Jacobs, M. B., Ed. The Chemistry and Technology of Food and Food Products. Interscience Pub., Inc., New York (1944). Vol. 1.



COURTESY OF THE FITCH FLOUR SYSTEM

FIG. 6. Schematic drawing showing unloading of bulk car and drawing off flour to storage bins and subsequent blending.

by rail or truck to the bakery. At the bakery, the bin is placed on a tilt rack. Weighing platforms are built in single, double, triple and quadruple units. A variable speed drive can be furnished for the discharge on each tilt rack so that any proportion of flour can be blended into the screw discharge lift (Figure 7). The system

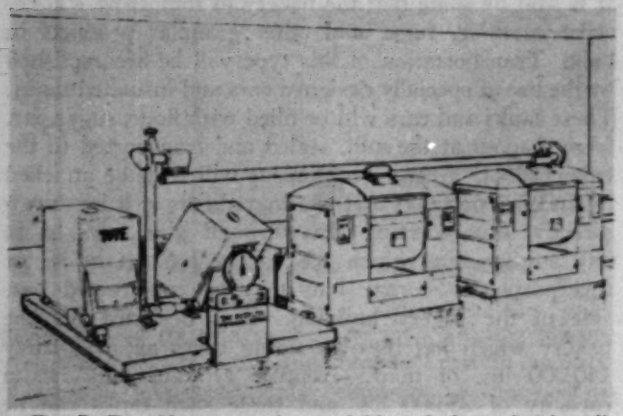


FIG. 7. Tote bins mounted on weighing platform showing tilt rack and screw discharge lift. (Courtesy of Tote Eng. Inc. and Peerless Bread Machinery Corp.).

permits bakers to blend as many flours together as may be desired.

Prepared Mixes. Although prepared mixes were introduced approximately 30 years ago, it was not until recent years that they gained wider acceptance and usage in the baking industry. Several types of prepared mixes are used in the bakery. The cake doughnut mixes, with baking powder as the sole leavening agent, account for approximately 75% of all the fried cake doughnuts produced in this country. Other prepared mixes are yeast-raised doughnut, coffee cake and cake mixes which include white, yellow, spice and devil's food. The yeast-raised doughnut and coffee cake mixes have been used to a considerable extent and cake mixes are being experimented with in the baking industry. Cake mixes have shown wider usage in home baking. In producing quality blended products, strict control must be adhered to in their preparation. All raw materials must be carefully selected, stored and proper blending procedures must be followed. Flavors should be checked for their stability before incorporating in a dry blend and the moisture content of the finished mixes must be closely controlled. A test bake from every batch should show the baking quality of the blend. An illustration of an automatic scale setup for weighing ingredients in preparing dry mixes is shown in Figure 8.

Enrichment. Within recent years the enrichment of

FIG. 8. Automatic scale setup for weighing ingredients for making prepared mixes. (Courtesy of Doughnut Corp. of America).

bread has been made possible through the isolation and synethesis of vitamins. Thus it is possible for bakers to restore to white bread the nutritive factors which have been removed from the wheat by milling. During World War II, enrichment of flour and bread was made mandatory through a Federal enactment in the form of a War Food Order. The maximum and minimum requirements for such enrichment of white bread are shown in Table 4. Following the termination of the

TABLE 4

Proposed Standards for Enriched Bread

According to Federal Register, 8, No. 152, Aug. 3, 1943

	Milligrams Per Pound	
	Minimum	Maximum
Required		
Thiamin	1.1	1.8
Niacin	10.0	15.0
Riboflavin	0.7	1.6
Iron	8.0	12.5
Optional		
Calcium	300	800
Vitamin D (U.S.P. Units)	150	750

war emergency, there came a repeal of the War Food Order requiring enrichment of flour and bread and continued enrichment of these products became voluntary as far as Federal Agencies were concerned. Many states, however, have enacted Enrichment Laws. Thus, some 24 states at the present time have Enrichment Laws for certain baked goods. The enrichment of white bread may be accomplished by using enriched flour, by adding enrichment factors in concentrated form (enrichment tablets), or by a combination of both means. The major part of the white bread made today is enriched.

Active Dry Yeast. Active dry yeast in yeast-raised bakery goods had a widespread usage in the Armed Services during the past war. Its advantages such as

elimination of refrigeration, ability to withstand a long storage period and less storage space requirements were advantageous to the Armed Services. Due to the smaller amount of moisture present in active dry yeast, the solids content is approximately 92% in comparison to the 30% solids present in compressed yeast. Active dry yeast is prepared similarly to wet yeast except for the drying conditions. The active dry yeast is said to be a hardier strain and can retain baking strength and activity for many weeks when stored at 75-80° F. and many months when stored at 40° F. Manufacturers of active dry yeast claim that it is possible for the baker to limit his yeast purchases to a semi-monthly or monthly basis and produce bakery products with active dry yeast which compare in quality with wet yeast bakery products. It is reported that several bakers in the country are using active dry yeast commercially today. It has been sold for home baking for some time.

Pan Glaze. In recent years the use of silicone coatings dipped or sprayed on cleaned and prepared pans for the purpose of eliminating greasing has attracted much attention in the baking industry. Briefly, the process consists of "burning out" the pans and applying a silicone coating inside and out with an extra heavy coating on the straps to prevent rusting. The coated pans are then cured at temperatures not exceeding 425° F. Pan glazing is said to give easy release of baked bread for 100 to 200 bakings. Glazed pans have been tried in many bakeries. Some bakers are satisfied with their performance while others are not. Some users have not experienced the number of bakes claimed by the manufacturer. The coating and cleaning of pans presents a problem and extreme care must be exercised with the glaze as it is inflammable. Glazing companies are being set up for providing cleaning and glazing services for the baker. Further experimental work with pan glazing is necessary before universal acceptance of the process becomes possible.

Coated Pans. A new type of pan material developed within recent years is aluminized steel. The sheet steel, instead of being tinned, is coated with molten aluminum by a special process resulting in a coating of 1/1,000 of an inch in thickness. The coating is said to be so thoroughly bonded to the steel base that it serves as a permanent finish which will outlast the useful life of the pan. Although more costly than the tinned pans, the aluminized pans used for bread are claimed to offer greater durability, excellent corrosion resistance, convenience and elimination of the "burning out" process.

Another new coating has been developed for tinned pans which is used to eliminate the "burning out" process. The pan is coated with an oleo-resinous material on the outside that has the quality of absorbing heat rather than reflecting it. By the time the coating wears off, the pans are said to be properly conditioned and no further coating or "burning out" will be needed.

Some bakeries are experimenting on a large scale with both the aluminized and oleo-resin coated pans.

Canned Bread. Canned bread was developed by the Quartermaster Corps during the past war with the intention of partially, or completely, replacing the biscuit and cracker rations. The men in the services considered this bread to be more tasty and appetizing than the biscuit rations. The possibility of this item as a carrier of the B-complex vitamin was also considered. Figure 9 illustrates the product. The drab olive enamel finish on the exterior of the container is needed to get the proper heat absorption for producing the desired crust color. Some interest from the commercial standpoint has been shown for the product with respect to its usage for camping, picnics and limited general use. The product is good but lacks that soft, fluffy character that is present in regular bread and desired by the public.

Oakes Continuous Mixing Machine. Figure 10 is a picture of the Oakes continuous mixer. With certain

FIG. 9. Canned bread. (Courtesy of Quartermaster Food & Container Institute).

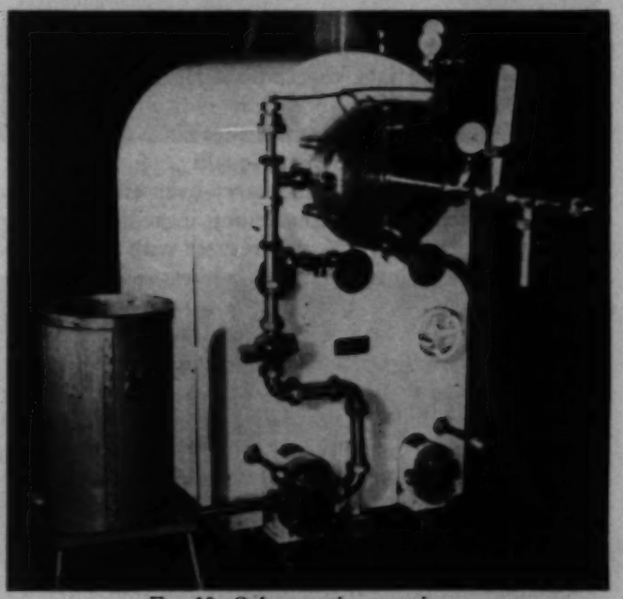


FIG. 10. Oakes continuous mixer.

type cakes such as sponge layers, this machine makes it possible to incorporate more air into the eggs with the result of obtaining good volume. Also, a more stable emulsion and thorough mix can be obtained. The time saved is not too great when considering the additional time involved for the preparation of the premix. In the operation of the machine, a premix of ingredients is poured into the metal container and is drawn through the pipes into the upper body of the machine (shown as the circular mass of stainless steel metal). At this point, air is also beaten into the premix with the aid of a series of knifing blades which revolve at controlled speeds. The valves on the upper right end of the machine con-

trol the air pressure which is being forced into the premix. The mix containing incorporated air is then drawn out the long stainless steel tube extending outward from the front of the machine and is passed down through a chute to the depositors. The Oakes continuous mixer also can be used for other type cakes and in the preparation of marshmallow and mayonnaise. Another machine manufactured by Marco Company, Inc. also is used for continuous mixing.

Emulsifying Agents. Within the past few years a considerable amount of research has been carried on by large baking concerns and manufacturers of bakery ingredients with respect to emulsifying agents used for retarding bread firming. Notable among these agents are the surface active monoglycerides and polyoxyethylene monostearate. Both types of agents have been claimed by investigators to enhance softness, tenderness and keeping-quality in bakery products, especially bread.

Antioxidants. During the war and the intervening years following the war, new developments in antioxidants which extend the keeping-quality of fats, particularly lard, have been investigated. Such antioxygenic agents as nordihydroguairetic acid (NDGA); butylated hydroxyanisole containing citric acid (AMI 72); alpha, beta and gamma tocopherols; gum guaiac; gallic acid and its ester derivatives; and synergistic components like citric, ascorbic, and phosphoric acids have demonstrated the property of retarding rancidity of fats, especially animal fats. Antioxidants are beginning to be used in fats, especially lard, but not to any great extent. There is very little indication that the baker is adding them to his own products. It is highly desirable to have the keeping-quality of the baked product extended through the carry-over effect of the antioxidant present in the shortening ingredient. Some success has been shown in this respect with the longer shelf-life items such as crackers, saltines, potato chips, and potato sticks.

Cross Graining. One of the more recent mechanical developments designed for improving the internal characteristics of dough is that of cross graining. With this type of molding, the dough is sheeted out and rolled at right angles in comparison to the conventional type of molding. An illustration of the cross graining machine is shown in Figure 11. The process is said to promote a better grain and texture in bread which, in turn, results in a brighter and more tender crumb. Elimination of holes, streaks or cores are thus effected. A slightly longer proof time is needed due to the gases having been expelled to a greater extent during the cross graining process.

The Patterson Mixatron. The Patterson Mixatron is a complex instrument which charts curves showing the relative consistency of sponges and doughs. The manufacturer claims that the instrument simplifies the setting up of proper mixing time and absorption conditions on new flours. Some of the other advantages listed by the manufacturer with reference to sponges and doughs are:

Full control of uniformity provided by the chart information, record of gross errors in ingredient formulation and constant supervision in relation to the human and mechanical factors which affect the mixing operation.

New types of electronic circuits are used which measure the differential instantaneous consistency of the dough and, in turn, translate the information into electrical impulses which are registered on the recording meter. The machine can be installed in the mixing room, on the superintendent's office desk, or any part of the bakery for that matter. During the operation of the mixer, the Mixatron's chart moves constantly and stops when the mixer operation ceases. A view of the Patterson Mixatron is shown in Figure 12.

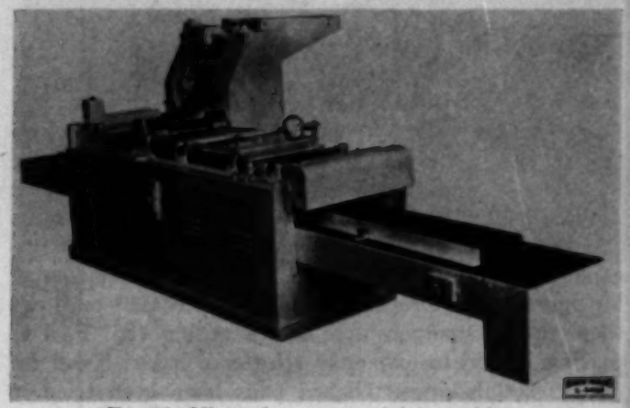


FIG. 11. View of a cross-graining machine.

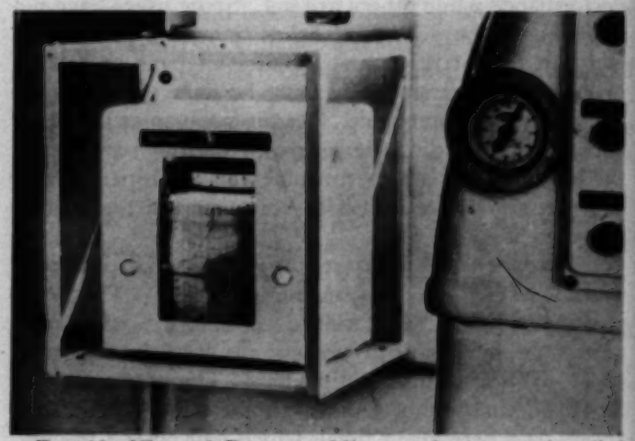


FIG. 12. View of Patterson Mixatron instrument installed along side of mixer. (Courtesy of C. J. Patterson Co.).

Improved Packaging. Ever since the advent of cellophane, packaging has been directed towards displaying bakery items in a sort of window style. Different styles of packaging are now available which display the products very well and also have a tight seal for preventing direct contact of the products with the atmosphere and preserve freshness. Figure 13 shows several types of improved packaging. The use of aluminum foil and pliofilm has been demonstrated to provide a tighter seal in packaging. However, aluminum foil has the disadvantage of lack of visibility for showing the contained items and additional cost above that of cellophane. Pliofilm has been found to impart a rubbery odor to high fat products when stored at warm temperatures.

FIG. 13. Types of improved packaging.

Bake-In and Molding Containers. Figure 14, a, b and c illustrates three types of bake-in containers which are used commercially to a small extent. Such type containers have their advantage in eliminating additional handling operations. The container shown in Figure 14a is a lightweight tinned pan. In Figure 14b the container is made of a heavy weight of aluminum foil, and the one shown in Figure 14c is composed of cardboard. In all cases the products are baked and retailed in the same containers.

In Figure 15a and b mold forming containers are shown which augment preparatory procedures in the bakery. The light color on the bottom of the heart shaped cake is due to the insulation of the cardboard.

FIG. 14. Bake-in containers. a. Light weight tinned pans. b. Heavy aluminum foil containers. c. Bake-a-cake board.

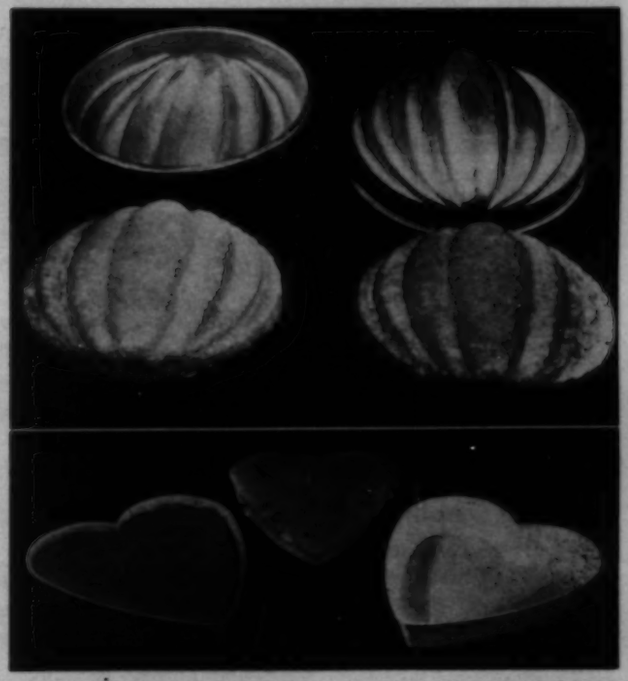


FIG. 15. Molding containers. a. Metal type for pumpkin ribs. b. Cardboard single use type.

The metal molds can be used over and over again but the cardboard container is discarded after its initial usage.

Bread Standards. At the present time standards are being developed for bread and rolls or buns. This development of standards is a definite trend and once they are set up only those ingredients listed will be used by baking companies involved in interstate commerce. When promulgated, Federal Standards of identity for bread and rolls or buns will apply to about six various types of these products.

Frozen Bakery Goods. Although frozen bakery products have received an unusually large amount of publicity during the past few years, this part of the industry is still in its infancy. Many bakery products can be frozen successfully but, in many cases, there is little advantage in them over the fresh product. Frozen unbaked rolls and pies can be purchased by the housewife in the made-up condition and baked in the home. The housewife can save the time it would take her to prepare these items for her own baking but more time, of course, is involved than if she were to go and buy the ready baked product. She has the advantage, however, of acquiring a freshly baked product from her own oven. Frozen items of the type just mentioned are illustrated in Figure 16. With respect to frozen roll

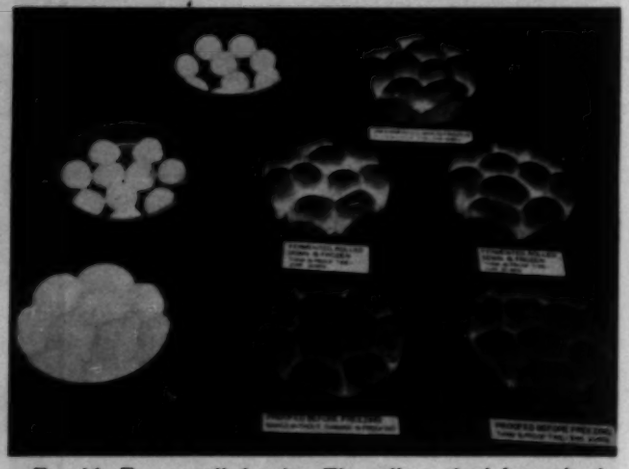


FIG. 16. Frozen roll doughs. The rolls at the left are in the unbaked and frozen condition. Before baking the rolls had been stored at —10° F. for one month. The yeast was most active in the rolls which were unfermented before freezing (top rolls) and made the best baked product.

doughs we have found that the yeast retains its fermentation activity and survival over a longer period of subfreezing temperature storage if the roll doughs are properly frozen soon after the makeup operation and before any appreciable fermentation takes place. There are other frozen bakery items which can be made up in large quantities in the bakery and held in frozen condition and gradually released for consumption sales.

Defrosting and Heating With Radio-Frequency Heat. It has been demonstrated that radio-frequency heat can be used successfully to defrost various vegetables, fruits, eggs and other foods, while in the container, within minutes. This is a considerable saving in time which, according to conventional methods of defrosting, can take anywhere from hours to days, depending on the size of the container. Frozen fruits and eggs

FIG. 17. Defrosting frozen cherries by radio-frequency heat. Placing frozen cherries in electronic oven.

can be defrosted electronically in the bakery plant as they are needed. A view of frozen cherries about to be placed in the electronic oven is shown in Figure 17. The time necessary to defrost the illustrated section of frozen cherries amounts to only a few minutes.

Radio-frequency heat also has been used to sterilize packaged bakery products with respect to mold contamination. Packaged products such as bread, rolls, buns, and Boston brown bread which had been heated to 140° F. showed no evidence of mold growth during a storage period of two weeks. The non-heated controls molded within a few days.

Closer Standardization and Quality Control of Ingredients. Practically all of the larger baking concerns, and those where it can be afforded, maintain a control laboratory designed for upgrading their products. Such a system consists of a scoring department, experimental bakery, chemical and bacteriological laboratory, and a research department. The scoring department consists of trained individuals who scientifically evaluate the baked products with reference to external and internal appearance, color, taste, aroma, etc. Such a method helps the baker to secure quality merchandise and maintain this quality once it is attained. The experimental bakery constantly experiments with new formulas and methods and acts as a pilot testing plant. The chemical and bacteriological laboratory serve to test all ingredients which are used in baking and reports whether or not all of these ingredients meet the standard specifications. Such laboratory control informs the bakery of the quality of raw materials and induces the ingredient manufacturer to constantly upgrade his product. The research department, as the name implies, is concerned with new developments and improved methods of control. It is the dynamic part of the setup and the place where new ideas and practices are born which, upon materializing, lead to growth of the industry and improvement of bakery products.

Acknowledgment

The author wishes to extend his appreciation to Mr. W. J. Godkin and Mr. T. R. Regenie for their assistance in the preparation of this paper.

Industrial and Legal Viewpoints

Stabilization of Farm Prices[a]

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(Received for publication, October 4, 1949)

Factors affecting fluctuation in prices of agricultural commodities are discussed. The difference between protecting farmers against extreme price declines and guaranteeing them a particular income is outlined. The impossibility and undesirability of completely stabilizing farm prices is emphasized. However, it is concluded that Government support at stop-loss levels are an appropriate aim of agricultural policy to insure the production of essential crops and to contribute toward general economic stability.

Discussion of the economic issues involved in the stabilization of farm prices is appropriate at any time, because of the large importance of the subject. It is especially timely now, because the issues are being debated before Congressional Committees.

In this discussion I propose to center attention on fluctuations in annual average prices. This is not, of course, the only type of variation which occurs. In addition to changing from year to year, agricultural prices also vary within the year—from day to day, from week to week, and from month to month. There is not, of course, any sharp dividing line between intraseasonal and interseasonal price changes—the one merges into the other — but it is convenient to consider them separately.

For purposes of presentation I have divided the topic into four parts:

1. Extent of fluctuations in farm prices.
2. Causes of fluctuations in farm prices.
3. Measures for stabilizing farm prices.
4. Desirability of stabilizing farm prices.

I

Very substantial changes from year to year are characteristic of the prices of most agricultural commodities. California summer oranges provide a good illustration of the instability in prices of individual farm products. The extent of the variation in the seasonal average prices of California summer oranges during the past 25 years is illustrated by the following: In 1925 the average f. o. b. price was 69 percent higher than in 1924, and 47 percent higher than in 1926. The 1928 price was 40 percent higher than in 1927, and 113 percent higher than in 1929; the 1930 price was 118 percent higher than in 1929, and 159 percent higher than in 1931. Summer orange prices also fluctuated widely during the 1930's. For example, the average f. o. b. price was 132 percent higher in 1937 than in 1938. These price fluctuations still persist. The average f. o. b. price was 63 percent higher in 1946 than in 1947; and the price in 1949 promises to be substantially higher than in 1948.

II

Most of the variation in annual average f. o. b. prices of California summer oranges can be accounted for by changes in supply and demand conditions. Among the factors which our analyses have revealed to be important are the following: (1) volume of California orange shipments, (2) size of California oranges, (3) volume of orange shipments from other areas, mainly Florida and Texas, (4) supplies of competing products such as grapefruit and canned juices, (5) buying power of consumers, (6) trend of demand, (7) export outlets, and (8) marketing margins.

It is not my intention to discuss in detail the specific effects of each of these factors upon orange prices. Rather, I want merely to make three points. First, prices vary little from year to year in the absence of changes in one or more of these factors. Second, prices may vary little from year to year even with changes in two or more of these factors, provided the changes are such as to offset each other. And third, wide swings in prices occur when all or most of the factors operate in the same direction. Then we have either very high prices or very low prices. The combination of small shipments of good-size, high-quality fruit from California coupled with small orange shipments from Florida and Texas, short supplies of competing products, large national income, and good export markets inevitably brings high prices. And conversely, the combination of large shipments of small-size, poor-quality fruit from this state coupled with large orange shipments from Florida and Texas, heavy supplies of competing products, low national income and restricted export markets, inevitably brings low prices.

Examination of the causes of fluctuations in farm prices suggests that stabilization would require either the elimination of changes in the factors which influence prices or the manipulation of the factors in such a way as to offset each other.

III

I should like to turn then to the consideration of measures for stabilizing farm prices.

Among the important causes of fluctuation in average annual prices of crops are changes in the volume of production arising from variations in yields per acre and in acreage harvested.

Average yields per acre vary from year to year, mainly because of changes in weather conditions. Thus

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 11, 1949.

far man has not succeeded in stabilizing the weather. Substantial variation in yields per acre continues to be the rule rather than the exception.

Attempts at stabilizing prices against fluctuations in production caused by variations in yields per acre have taken two quite different forms. One line of attack on the problem has been diversion from normal trade channels; the other has been storage.

In the case of *perishable* products diversion from normal trade channels, an extreme form of which is outright destruction, is the only means of stabilizing commercial shipments in the event of a large crop. But this device is not, of course, effective when the crop is short. The size of the crop necessarily sets the upper limit on shipments. While it is possible to ship less than is available for shipment, it is not possible to ship more. Hence, in the case of perishable products stabilization of commercial shipments against fluctuations in annual production cannot be complete.

In the case of *nonperishable* products, on the other hand, supplies can be carried over from large crop years to short crop years, and shipments can be evened out despite large fluctuations in annual production. The concept of the ever-normal granary is essentially sound, *provided* it is confined to stabilizing market supplies against fluctuations in average yields per acre due to variations in weather. These fluctuations in yields per acre tend to be quite random in character. A run of either high or low yields due to weather conditions does not, as a rule, continue indefinitely. Hence a storage agency can have reasonable assurance of the opportunity of disposing of stocks acquired in years of above average yields per acre. It should perhaps be mentioned that the storage agency may be prevented from taking advantage of this opportunity because of the price-depressing effects at the time. There seems to be much less opposition to filling the ever-normal granary than to emptying it!

Now if storage is a suitable method for stabilizing market supplies against fluctuations in yields per acre, why is it not also a suitable method for stabilizing market supplies against fluctuations in acreage? That is, why is it not feasible to carry over a portion of the crop from a year when plantings are above normal to a year when plantings are below normal? The answer is that it would be, provided there is reasonable assurance that a large acreage will shortly be followed by a small acreage. But, in fact, no such assurance can be had! Changes in acreage from year to year are not random in character. Rather they are determined largely by prospects of profit or loss. So long as comparatively good returns are assured, large plantings will be continued, however great storage stocks may become.

Recognition of this fact led the Federal Farm Board to advocate and the Agricultural Adjustment Administration to institute acreage control. Acreage allotments proved to be a reasonably effective method of regulating plantings. But after the first year or two they largely lost their effectiveness in also regulating production. Farmers soon found ways of increasing the level of yields on the restricted acreage. By 1940-1942 crops of corn, wheat, and tobacco were all above the 1931-1933 averages, despite reductions of from 13 to 20 percent in acreage. The cotton crop was reduced, but it took a 38 percent decrease in acreage to bring about a 17 percent shrinkage in production.

On the basis of past experience it seems clear that much tighter controls than any yet exercised will be necessary, if production of agricultural commodities is to be effectively regulated. In addition to control of acreage, it will be necessary to regulate cropping practices, the amount of fertilizer, the kind of seed, and the hours of labor. I am not advocating such controls. I am merely reporting that if farmers insist upon a high degree of stabilization of production of individual agricultural products, they must also submit to a high degree of regimentation.

The question also arises regarding the use of storage for stabilizing prices against fluctuations in demand. Why, for example, should not stocks be acquired in years of low demand for disposal in years of high demand. That, of course, is what the Commodity Credit Corporation actually did. The heavy stocks of corn, wheat, and cotton which it had accumulated before the war served to help meet wartime demands. Its predecessor—the Federal Farm Board—was not, however, as fortunate. As you will recall, that agency tried to offset the adverse effects of the 1930-1932 depression upon the prices of wheat and cotton by means of loans and purchases. It acquired large stocks while demand was still relatively high but released them when demand was much lower. Its operations accentuated rather than moderated the fluctuations in farm prices, and it lost nearly 400 million dollars in the process.

The real difficulty with attempting to stabilize prices against variations in demand by means of storage operations stems from the nonrandom character of demand fluctuations. One cannot be confident that prosperity is "just around the corner." Hence, the ever- normal granary may overflow while demand is still receding. A reservoir that is filled in the winter does not prevent spring floods.

There is grave doubt that farm prices can be held steady against pronounced changes in demand such as occur during the business cycle. Recurrent booms and depressions are responsible for much of the instability in the prices of all farm products.

Consider for a moment the development since the outbreak of World War II. The index of prices received by farmers in 1948 averaged 287 as against 100 in 1940, an increase of 187 percent. Total production of agricultural products was nearly one-fourth larger in 1948 than in 1940. The great rise in prices, therefore, was clearly not the result of short supplies. Rather, it was the result of extraordinarily good demand conditions both at home and abroad.

The basis for the large domestic demand was the high level of national income. In 1948 total personal income of individuals in this country amounted to 214 billion dollars, as against 78 billion dollars in 1940. Personal income taxes were, of course, much higher in 1948 than before the war, but they absorbed only a small part of the increase in total income. Disposable income was 154 percent larger in 1948 than in 1940. People in this

country had lots of money, and they insisted on spending it.

Just as booms cause prices of agricultural products to rise rapidly, depressions cause them to fall rapidly. During the past 40 years this country has experienced two major depressions; the first was shortly after World War I; the second was in the early 1930's. From June 1920 to June 1921 the index of prices received by farmers fell 52 percent; from January 1930 to January 1933 it fell 58 percent. Prices of many individual agricultural products dropped even more.

Some effort was made to keep farm prices from falling in 1930-1933, and very substantial effort was made to keep them from rising during the period 1942-1946. But neither of these efforts was apparently very successful. The best that can be said is that they may have tempered the decline in 1930-1933, and they may have tempered the rise in 1942-1946. But they did not result in any high degree of price stabilization.

Both historical evidence and economic reasoning lead me to the conclusion that the basic solution of the problem of stabilizing farm prices against fluctuations in demand is to stabilize demand itself. In making this statement I am not necessarily implying that demand can be stabilized. What I am saying is that farm prices cannot be held steady in the presence of recurrent booms and depressions. Whether booms and depressions can be avoided is an entirely different issue. This is a most complex subject and discussion of it would take us far afield. But I may say that stabilization of farm prices would not in itself prevent booms and depressions, although conceivably it could help to moderate them.

IV

I come now to the question of the desirability of stabilizing farm prices against fluctuations in supply and demand conditions. In considering this question I suggest that we examine different types of cases.

First, let us examine the case of stabilizing prices against fluctuations in yields per acre. If prices were held at the same level in years of low average yields as in years of high average yields, gross returns per acre would vary widely. They would be large when yields were high and small when yields were low. In this case, stable prices would mean unstable returns per acre. Growers might welcome the situation in which prices would be prevented from dropping when yields per acre were high, but I doubt that they would be equally content to have prices held down when yields per acre were low. It can, I think, be argued that growers can afford to take lower prices in years of high yields per acre since their costs per unit are less; and that they need higher prices in years of low yields per acre, since their costs per unit are greater.

I would not, however, rest my case solely on the grounds that, from the standpoint of growers, stable incomes per acre are more to be desired than stable prices per unit of product. Other considerations also point to the desirability of permitting prices to vary inversely with changes in market supplies.

Flexible prices serve the useful purpose of keeping current consumption adjusted to existing supplies. This is a highly important function. In years of large output, movement through trade channels into consumption needs to be stepped up appreciably in order to avoid waste of perishable products and burdensome carryovers of nonperishable ones. And in years of small crops, consumption obviously has to be restricted. By permitting prices to decline in periods of large supplies and to rise in periods of short supplies, a reasonably good balance is automatically maintained between current consumption and current production. If price changes are to be prohibited, some other means will have to be found to induce consumers to expand their purchases when supplies are large and to compel consumers to contract their purchases when supplies are short.

A closely related question is whether prices should be permitted to reflect changes in basic cost conditions in the industry. My answer to this question is yes. On the assumption that the demand for the product remains unchanged, prices should be permitted to rise with increasing costs in order to avoid a shortage of the product; and prices should be permitted to fall with decreasing costs in order to avoid a surplus of the product. With rising costs but no increase in price, growers would find it less profitable to produce the commodity, and would tend to shift to other products. The supply of the commodity would soon become inadequate to meet the demand for it at the stabilized price. Consumers would want to buy more of the commodity than producers would be willing to supply. Then the government would have the task either of requiring producers to expand production at a financial sacrifice to them, or of preventing consumers from buying all of the commodity they are able and willing to purchase.

The reverse of the situation would also create serious difficulty. With falling costs but no decrease in price, growers would find it more profitable to produce the commodity and hence would tend to expand its production. In this case the supply of the commodity would soon exceed the demand for it at the stabilized price. Producers would want to grow more of the commodity than consumers would be willing to buy. Again the government would be called upon either to prevent producers from growing all of the commodity that it is profitable for them to grow, or to compel consumers to buy more of the commodity than they want to buy.

Consider next the case of holding prices constant in the face of a change in basic demand conditions. With an increase in the demand for the commodity but no rise in price, consumers would want to expand their purchases. But producers would not want to supply the additional quantity demanded, since with no rise in price permitted it would not be profitable for them to do so. A shortage would develop.

On the other hand, with a decrease in demand but no fall in price, consumers would curtail their purchases. But producers would find it profitable to continue to grow as much of the commodity as before. A surplus would develop.

Price changes then serve not only in adjusting current consumption to existing supplies but also in directing future production in line with changes in basic demand and cost conditions. In an economy which re-

tains both freedom of choice in consumption and freedom of enterprise in production the economic incentive is perhaps the most effective device for bringing about needed adjustments. Through the effect of changes in relative prices and costs upon net returns, a powerful incentive is provided farmers for shifting from the production of those products whose costs have increased or whose demand has decreased. In fact there is a double incentive for shifting: one, to avoid loss from continuation of production of the lower-priced products; and the other, to obtain a profit from the production of the higher-priced ones. Stabilizing prices in the face of changes in basic cost and demand conditions would prevent needed production adjustments within agriculture, and would lead to shortages of some commodities and surpluses of others.

V

The Agricultural Act of 1948 provides for a shift from rigid to flexible price supports on farm products at the end of the 1949 crop marketing season, and permits price supports to be as low as 60 percent of revised parity prices in years of large supplies. This Act seems to me to be a move in the right direction. It is an approach to the concept of stop-loss price floors.

Valid criticisms of the Act may be made, and experience with it may reveal weaknesses which are not now apparent. Nevertheless I am confident that it is much better than the rigid and high price supports now prevailing on basic and Steagall commodities, and I suspect that it is also much better than Secretary Brannan's proposal.

Government price supports for farm products at *genuine* stop-loss levels are, I suggest, a defensible goal of agricultural policy. By such supports, farmers would be provided some protection against abnormally low prices arising from extraordinarily large crops, from failure of export outlets, or from drastic shrinkage of domestic markets. But this sort of protection would fall far short of guaranteeing farmers perpetual prosperity.

There is a very basic difference between the concepts of protecting farmers against extreme price declines and guaranteeing them the particular incomes to which they have become accustomed or to which they feel they are entitled. The first is an attainable goal in a free enterprise system. The second is an illusion under any economic system; it cannot be accomplished under socialism, communism, or fascism, although efforts to attain it could lead to a totalitarian form of government.

If government is to guarantee any one occupational group the particular share of the national income to which it believes itself entitled, it should do the same for all other occupational groups. The sum of these shares will surely exceed one hundred, and consequently one or more of them must be scaled down. Objective criteria for determining what the "fair shares" ought to be are yet to be developed, despite the fact that the problem has occupied the minds of able men for many generations. I personally doubt that it is possible to develop a formula for dividing the national income among occupational groups which will appeal to all as fair, equitable, and just.

In conclusion may I summarize my remarks under three points:

1. It is not, I think, possible to devise a scheme for the complete stabilization of farm prices which is economically sound, administratively practicable, legally enforceable, and publicly acceptable. Unless a program meets these four conditions of economy, practicability, enforceability, and acceptability, it is not likely to last very long. But any program which does meet them is not likely to eliminate all fluctuations in farm prices.

2. Even if it were possible to hold farm prices steady, it would not, I suggest, be desirable to do so. Price changes play an important role in an economic system which permits freedom of choice in consumption and freedom of enterprise in production. That role is to keep current consumption adjusted to existing supplies and to keep production adjusted to changes in basic cost and demand conditions.

3. Government price supports at *genuine* stop-loss levels are an appropriate aim of agricultural policy. Such price supports would afford protection to farmers in periods of acute distress without interfering unduly with needed adjustments in production and consumption, and without making farmers the wards of the government.

REFRIGERATION IN RESTAURANTS IS LATEST ASRE PUBLICATION

Restaurant refrigeration is thoroughly discussed in a 10-page pamphlet recently issued by the American Society of Refrigerating Engineers, 40 West 40 Street, New York 19, N. Y. This is the only bulletin devoted exclusively to the refrigeration problems encountered in restaurant refrigeration.

It is known that proper storage facilities are essential in every food service operation and AD 6-R, "Refrigeration in Restaurants," gives the operating characteristics and individual functions of the many pieces of refrigeration equipment used in a restaurant.

Temperature data are given for long and short time storage of commodities commonly handled in restaurants (fresh and frozen food). Another section is devoted to describing and illustrating the various types of reach-in refrigerators and walk-in coolers and includes advice on the proper condensing unit and evaporator for each cooler installation. Other topics discussed are defrosting, water cooling, beverage cooling, ice cream cabinets, ice making, and other refrigeration fixtures such as display refrigerators and soda fountains.

This pamphlet was written by Robert A. Kramer, sales engineer for Frigidaire Division of General Motors Corp.

Copies may be obtained from ASRE headquarters for 50c each.

Industrial and Legal Viewpoints

Technological Problems in the Fishery Industries[a]

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(Received for publication, February 19, 1949)

Technological problems encountered in processing fish are described.

To the average person, the mention of the fishing industry means a trip on a small sports fishing boat, or buying fish at a neighborhood retail fish store. Very few realize the size and scope of this industry. It isn't as large as the meat industry, of course, but it isn't a small business by any standard. In an average pre-war year 4,400,000,000 pounds of fish were landed, with a final sales value of $596,000,000.

All industries have problems, but the fishing industry has more than its share. The following are a few of the major ones.

The first problem is not strictly a technological one but it has a marked effect on the technologist. The problem is that the fishing industry is a very old established industry which is set in its ways. Most of the people in it have grown up in the industry, and incidentally have made money in it. To them, the methods they have been using for years are satisfactory, and they are reluctant to accept new procedures until their competitors have tried them and have found them an advantage which is expressed in dollars and cents. This is to be expected in an industry having the history and background of the fisheries, but it makes the technologist's work difficult. If he is fortunate enough to work out his problems successfully, he must then sell his superiors, or the industry, on the ideas in order to put them into effect. It is difficult, but it can be done—and has been done—and each success makes the industry in general more receptive to new ideas.

A second problem, along the same lines, is that most of the companies in the fisheries are small and cannot afford research even if they wanted it. This means that with the exception of a few of the larger companies, all of the research for the fisheries must be done by the Government, State or University laboratories, and the support which has been given to Government research has not been great. For example, in a typical pre-war year the Government spent 82c per ton of food in the fisheries and $7.04 per ton of food in agriculture.[b] The industry needs technologists and technological research but how to get them is a problem.

One of the complicating factors in fisheries is that there are over 550 species of fish and shell fish in the United States, and nearly every species of fish is markedly different from the other. Also, even within each species there is often a difference in texture, keeping quality, and flavor, depending on the locality in which the fish are caught. With each species there is a problem for the technologist. Different species of fish can not all be handled the same. There are peculiarities all along the line from the actual method of catching through plant processing, and even into final retail sales. It is a well known fact that the people in certain areas of this country like one type of fish and will have no other, while other sections have opposite tastes. New England, for example, likes haddock over cod in a ratio of approximately 5 to 1. In some mid-west sections cod far outsells haddock. Pittsburgh likes whiting while certain other sections will not touch it. The big question is why all sections do not eat all types of fish. Perhaps it is a matter of education. Whatever the reason, it helps to make fish handling difficult and gives the technologist another headache.

In order to give a better understanding of specific problems which are encountered in handling fish, a brief background of how fishery products are prepared for marketing is given. There are four major methods of preparing fish for shipment to the wholesale or retail market.

The first type is known as "round." This is a fish just as it was taken from the water and includes head, scales and entrails.

Second, are the "dressed and scaled." These fish have had the heads, entrails and scales removed but are not otherwise cut. Of course there are other variations of these methods, but they fall between these two.

Third, are fish steaks. Large fish are used for this and the steaks are made by cutting the cleaned or "dressed and scaled" fish cross-wise, through the backbone, into sections approximately ¾" to 1" thick. Such a steak will be almost circular in shape with skin on the outer surface and the cut backbone in the center.

The fourth method is fish fillets. Fillets are the meaty sides of the fish which are cut away from the backbone. They are lengthwise cuts. They may either be skinned or the skin left on depending on the species. Cod fillets, for example, are always skinned—haddock very seldom. Fillets are by far the most popular means of handling fish for they save on transportation by not having to ship the bones or other inedible parts. They are also the most convenient for the housewife to handle and are practically 100% edible.

Shellfish are handled a little differently. Oysters and clams, for example, are either shipped alive in barrels or are shucked and shipped in water-tight containers. Lobsters and crabs are either shipped alive or they are cooked at the source of supply and the meat picked out and put in containers and shipped in ice.

These, in brief, are the four major methods of preparing fish. For each of these methods there are seven or eight variations in handling.

[a] Given at February 7, 1949 Meeting of the Institute of Food Technologists.

[b] Fishery Resources of the United States, 79th Congress, 1st Session, Senate Document No. 51, March 1945.

First, fish may be shipped or held in crushed ice. The ice, of course, lowers the temperature of the fish and delays spoilage by retarding bacterial multiplication. Round, and dressed and scaled fish are usually packed directly in the crushed ice—the skin acting as a protection against the melting ice. Fillets and steaks however are wrapped in parchment paper or cellophane and packed in slip-top metal cans, which are then packed in ice. The metal of the can conveys the cold to the fillets and keeps the fillets wrapped and clean. The cellophane, in combination with the can, prevents the water from the melting ice from leaching the soluble proteins from the cut surface of the fillets and thus reducing the flavor.

In New England, undoubtedly the most important method of keeping fish is by freezing. In January, 1949, there were 150 million pounds of frozen fish in U. S. freezers. All cuts of fish are frozen—from the round to the fillets. The whole type fish, with the skin on for protection, are either frozen loose in stacks or are put in large pans and frozen in blocks. The fish are held together in the block when the water between the closely packed fish freezes. Fillets and steaks which are to be frozen are first wrapped in cellophane or other suitable wrapping material and then packed in 5 or 10 pound waxed cardboard cartons and then placed in the freezer. The trend now is to pack the frozen 5 and 10 pound cartons of fish in 50 pound corrugated master cartons for ease in handling and shipping. The average temperature used for freezing the fish is from 20 to 30 degrees below 0° F. The temperature for frozen storage is approximately 0° F.

Another method of keeping fish is by smoking. The smoking of fish serves two purposes—first, to give the fish a distinct flavor, and second, to prolong the storage period before objectional changes or deterioration occurs. There are a number of degrees of smoking, ranging from a very faint smoked color, odor, and flavor to heavy, hard smoking as in kippers and dry, smoked fillets. In general, the heavier the smoke the longer the fish remain edible. Smoking is usually accompanied by some degree of salting. Light smoked and light salted products require refrigeration to prevent spoilage. This applies to such products as Finnan Haddie. The heavy smoked, heavy salted products will not spoil even if stored at room temperature.

Still another method of preserving fish is to salt them. The whole or split fish are packed with layers of salt in such a way that the fish make their own brine. Excess of salt is added so that any excess water from the fish will be taken up.

In combination with the salting is the process of drying the fish. Usually the fish are first heavily salted and held in the salt until the salt "strikes" or penetrates the entire depth of the fish. Then the fish are either dried in the air or by mechanical equipment until the moisture content is under 50%. Fish with a moisture content of 40% or lower will last almost indefinitely at room temperature.

Another method of keeping fish is to pickle them in a combination of salt, vinegar and spices.

The last, and perhaps the most important method of preserving fish is by canning. The problems experienced in canning fish are not too different from those in the normal food canning industry.

Approximately one-fourth of the fish caught do not find their way into the food markets. These fish are used to manufacture by-products. For the most part, that means that they are converted into fish meal and oil.

In each method of handling fish there are many problems, as there are with any food product, but in the fisheries the biggest of all is spoilage. To the average person there are only two classifications of the quality of fish. It is either fresh and edible, or spoiled and inedible, the spoilage being determined by the odor. The fisheries technologist knows that from the day the fish are caught, they begin to lose their flavor and that the loss in flavor is inversely proportional to the care with which they are handled. It is possible for fish to have no objectionable odor, and still be practically devoid of flavor. Unlike meat, the flavor of fish does not improve with age, so there is nothing in fresh and frozen fish processing which allows for the aging of the product.

With each of the previously described methods of handling or keeping fish, spoilage problems are encountered. The following are examples of the problems which may be present in each of the methods.

The first is fresh fish, and by "fresh" is meant "not frozen." Fish are classified by the trade as "fresh," "frozen," and "canned," depending upon the method of preservation. In the round uncut fish, as it is caught, the process of spoilage which occurs, is somewhat different from that of fillets. The skin acts as some protection against outside bacterial contamination, so spoilage naturally occurs from within. As soon as a fish dies and goes through rigor mortis—the enzymes of the flesh begin to act on the protein, and soften it. At the same time, the bacteria within the entrails begin to multiply and finally break through the entrail cavity wall and come in contact with the flesh. Since the enzymes have already prepared the flesh, the bacteria find a good medium for growth. In fish this action is very fast and therefore one of the essentials in processing fish is speed. It is a continual race with fresh fish to get them landed, to the plant, in ice, and to the retail market in the shortest possible time. With fish to be frozen, it is a race against time to get them in the freezer.

Fillets and steaks are very similar in regard to spoilage since both have cut surfaces of the flesh exposed. The fillets, for example, are cut from fish on specially designed tables in the plants. In many plants whole fish are handled on the same surface on which the fillets are cut. On this surface the whole fish deposit a slime material which is very viscous and difficult to remove by water. The slime is also a medium for bacteria growth. Also, bacteria laden material from the entrails may further contaminate the table surface. Therefore, when the fillet is cut, and the cut surface comes in contact with the contaminated table, it picks up large numbers of bacteria which may start the fillet on its way to spoilage. Since the flesh naturally is relatively soft, delicate and watery, it is not difficult for the bacteria to penetrate between the segments of flesh. Contamination of the fillet surface also comes from the knives and hands during handling.